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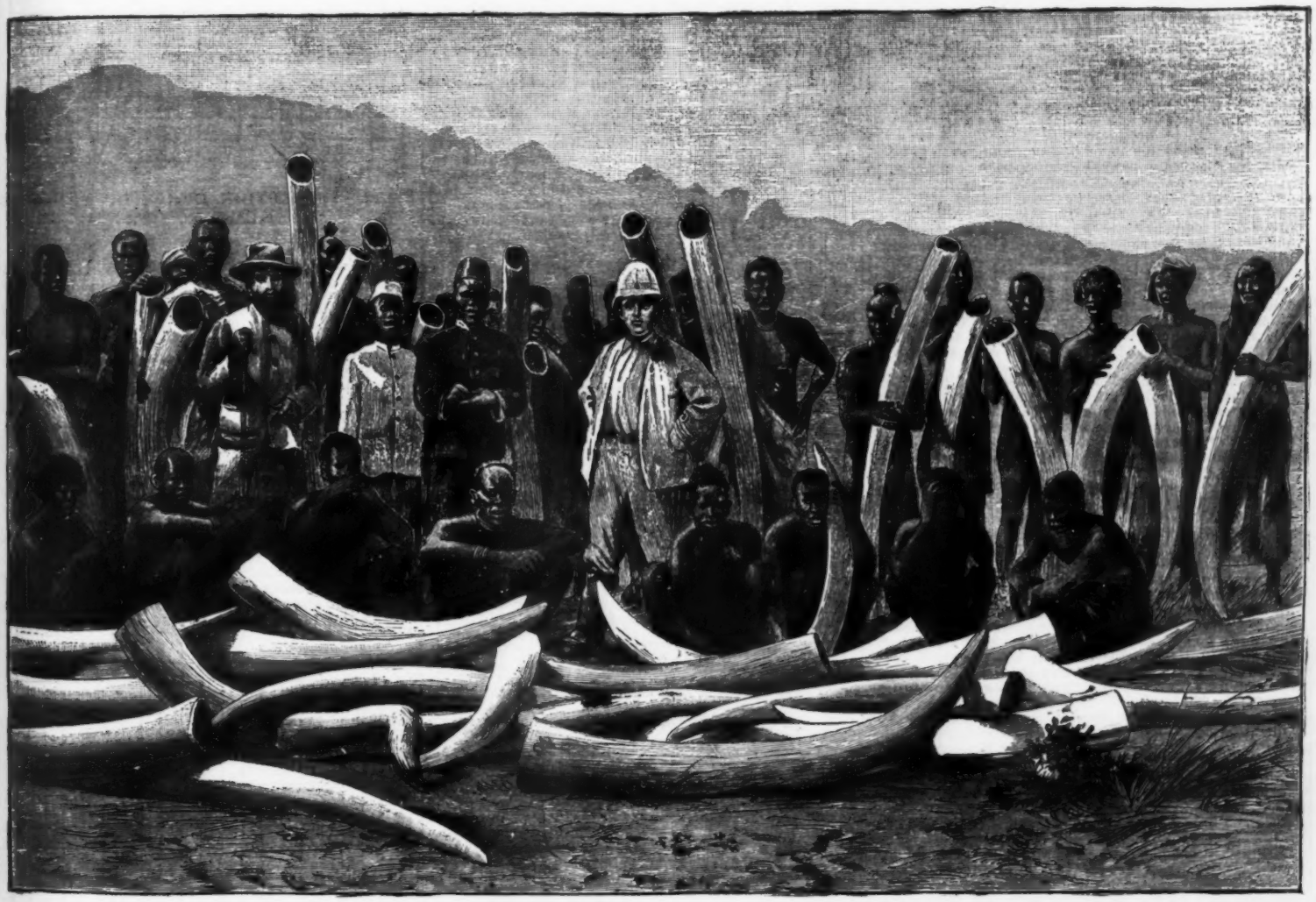
IVORY CAPTURED BY EMIN PASHA IN AFRICA.

EMIN PASHA, who reached the coast with Stanley in December, 1889, left again at the end of April, 1890, to establish a proper station at Victoria-Nyanza, in order to prevent the slave trade, as much as possible, to make treaties with the chiefs and to render the road from the lake to the coast safe.

During his march to the Lake Emin captured a large quantity of ivory, some of which is shown in our engraving, for which we are indebted to the *Illustrirte Zeitung*. 7,805 pounds of it, which had been gradually collected by the expedition, were stored at Bukumbi and were afterward sent to the coast by Langheld, Emin's first lieutenant. This ivory was worth about $35,000.

There are now two flourishing stations on Lake Victoria, Bukoba and Muansa, and the presence of the soldiers seems to have inspired the natives with confidence. It is to be hoped that the peace which now reigns there may long be maintained.—*Illustrirte Zeitung.*



AN AFRICAN IVORY CARAVAN.—FROM A PHOTOGRAPH TAKEN BY LIEUT. LANGHELD.

GEOGRAPHIC DISCOVERY IN AUSTRALIA.

IT was believed early in this century that the wholly unknown interior of Australia was watered by a great river system reaching the sea in the deep bays of the northwest part of the continent. It was to establish this supposed fact that Capt. Sir Philip King sailed along this coast in 1820, entering all the deep inlets to find some great river mouth. One day he sailed twenty-five miles up Hanover Bay, discovering a large river, which he named the Prince Regent. The next year he ascended the river for fifty miles. Nearly seventeen years elapsed before another expedition, under the command of Sir George Gray, was sent to Hanover Bay to complete the exploration of the river. The natives fell upon the party and wounded its leader so badly that he hastened back to civilization. From that day until last year no further effort was made to solve the problem of the Prince Regent River.

The latest *Petermann's Mitteilungen* contains a report of the expedition led a year ago by Mr. Joseph Bradshaw, of Melbourne, through this wholly unknown part of Australia. Landing at Wyndham, on Cambridge Gulf, with four white companions and two natives and a supply of provisions carried on pack horses, the little party plunged southwest into the unknown wilderness toward Prince Regent River. They had not gone far before they met natives as wild as any that were ever dismayed by the apparition of white men. The savages living along one river plunged into the water and swam across the stream upon the approach of the expedition.

Nearly all the way to the Prince Regent River the party traveled through tall grass. One species, known as the black oat grass, was from nine to twelve feet high, and it was difficult for the little caravan to force their way through it. At one place, where many enormous sandstone blocks were scattered over the plain, they found numerous large holes excavated in the bowlders in which the natives had stored the bones of their dead. The skeletons were not preserved intact, but the bones were packed closely together, and large stones covered them, apparently to prevent wild dingoes from scattering them. These curious mausoleums were found along a creek which Mr. Bradshaw named Sepulcher Creek. Here also he found a hitherto unknown fish of fine flavor which he was not able to find in any of the other rivers. He proved that the great desert of inner Australia does not extend thus far to the northwest, for the region through which he passed was watered by scores of creeks and rivers, while tropical vegetation luxuriantly flourished.

One day the party came to an unexpected impediment. A wall of high hills rose so precipitously that it was impossible to lead the horses up the slope. After hours of search a narrow valley was discovered between whose steep, high sides they traveled for about a mile, until they reached the summit of a comparatively level, well grassed plain. On this plateau they traveled for several days before they descended at the other edge. They found it very difficult to get through the tangle of hills bordering this little plateau on the western side, and for four days they were busy with axes under the glowing heat of the tropical sun cutting a road for the horses. A little beyond they ascended a mountain about 1,500 feet high, from which a very fine prospect extended in all directions.

On all sides stretched away the hills of lesser elevation, covered to their tops with thick growing grass, while as far as the eye could reach could be seen a great abundance of lagoons and watercourses fringed with papyrus and palms. It was a fine tropical prospect and very different from the semi-arid region which must begin not a great distance to the southeast.

Mr. Bradshaw was particularly struck with the work of white ants in the western part of the region he traversed. In one place, for instance, he discovered a perpendicular pillar with a diameter of about three feet and nearly ten feet in height. It stood in the middle of an enormous rock, at least forty feet from the nearest bit of soil. All the material for this structure must have been carried by these little insects forty to fifty feet, involving enormous labor.

As the party neared the Prince Regent River the country became more difficult to traverse on account of the steep hills, the great blocks of porphyry and sandstone in their way, and the tall grass. Sometimes they traveled for hours up a valley to find that it was a *cul de sac*, and all their labor was lost. At last they struck the Prince Regent River, and here they found many natives, doubtless the children of those that had attacked Sir George Gray. They were very shy, and were painted with red and white stripes in a wonderful manner. Many of them wore curious headdresses made of papyrus. As weapons they carried spears and nullis, as well as bows and arrows, but no boomerangs were seen.

The Prince Regent River was reached just a little above the point attained by Sir Philip King. In a straight line they were about 150 miles from their starting point, but they had traveled nearly double that distance. It is a beautiful river, about 200 feet wide at the place where Bradshaw struck it, and its waters coming from the Leopold Mountain chain, which is marked on the maps, are cold and refreshing. The party ascended the river, only to find that, about a day's journey above the place attained by Sir Philip

King, a splendid waterfall puts an end to navigation. This waterfall extends from bank to bank, and the entire volume of water has a perpendicular fall of thirty feet. They traveled for five days along the river bank above the waterfall to mountains through which the river flows, and along the rocky walls that hem in the narrow river they found many caverns on whose walls the natives had made paintings in red, black, white, brown, yellow and light blue. There were figures of men with profiles well drawn, and kangaroos, wallabies, crocodiles and other animals were graphically portrayed.

The noteworthy discovery was made that for a distance of fifty miles the Prince Regent River flows between two entirely different rock formations. The right shore is composed of basaltic rocks and the left is sandstone. The territory on the right bank is well wooded and grassed, while on the west there is found mostly only prickly spinifex and black oat grass, with bowlders strewn over the country.

Mr. Bradshaw was well satisfied with the result of his journey. His purpose was to ascertain if this region was adapted for cattle raising. He has satisfied himself fully that ranches can be established to good advantage at many places between the northern coast and Prince Regent River. South of the river vegetation changes its character and doubtless merges at no great distance into the almost verdureless expanses of the great thirst region of inner Australia. His party was very short of provisions before they got back to Cambridge Gulf, where they arrived on May 14. They, however, eked out their rations with wild turkeys, kangaroos, iguanas and fish, and at Cambridge Gulf they were glad to find again some of the comforts of civilization in the huts of the hospitable Chinese who occupy the most advanced post of civilization in that region.

Bradshaw's journey has revealed the character of one of the large unexplored regions of Australia. About the same time David Lindsay was crossing the greatest unknown expanse in southwest Australia. He has now gone north to traverse an unexplored district in the west central part of the continent, and when he completes this journey there will be no large region in Australia that is not fairly well known in its general aspects.—*N. Y. Sun.*

THE SCIENTIFIC VALUE OF LOVIBOND'S TINTOMETER.*

By F. W. EDRIDGE-GREEN, M.D.

FROM the time that color first commenced to interest scientific men, a method which would enable us to match colors and keep a record of them for further reference and examination has been desired. The present system of color nomenclature is unsatisfactory, as, in fact, all arbitrary systems of color naming must be on account of the varying degrees of color perception which are met with in different individuals.

Color is a sensation, and not an unalterable physical quality of bodies. The same substance may vary in color according to the conditions under which it is viewed. The rays of light which give rise to the sensation are unalterable, and it is the suppression or admixture of certain of these rays that gives rise to changes in the color of an object.

The tintometer is an instrument consisting of two tubes placed side by side on a stand. Both tubes are open at each end. At one end is an eyepiece through which both apertures in the tubes can be viewed. At the ends of the tubes, opposite the eyepiece, is an arrangement for holding the colored glasses and the substance to be measured. The colored substance is matched with colored glasses which are rose, yellow, and blue. The inventor has taken a glass very faintly tinted with each of these colors as a unit, and then constructed a series of glasses in sequence, in accordance with the number of units of the color in each glass.

The instrument is used as follows: In the case of transparent substances, a white porcelain plate serves for a background. The porcelain plate scatters white light in all directions, but gives a reflection sufficiently luminous for the purposes of the tintometer. On examining the light reflected from the porcelain plate with a spectroscope, it is found to give a continuous spectrum, the luminosity of the colors being diminished practically in the same degree. It is necessary that the spectroscopic composition of the light reflected from the porcelain plate be known, because a substance may appear white, without reflecting the spectral colors in an equal degree. Two or more of these colors may even be absent from the light reflected by a white substance. This fact may be demonstrated in the following manner: Let a spectrum be thrown on a screen with the aid of a prism. If a lens be inserted in the course of the rays, so that they will be focused on the screen they will be reunited at the point of focus, and again form white light. If an opaque object be interposed, so that one set of colored rays is cut off, the combination of the remaining rays will form a color having a hue complementary to that of the intercepted rays. For instance, if the intercepted rays be yellow, the remaining rays will appear blue. If, however, the blue as well as the yellow rays be intercepted, the reconstituted beam of light will again appear white. It is evident, therefore, that the removal of one or more pairs of complementary colors from white light will leave the light unaltered with regard to hue, though the luminosity will be correspondingly diminished. A substance, therefore, may be white without reflecting all the rays of the spectrum, provided that equal portions of complementary colors be removed.

In estimating color there is another point to be taken into consideration, and that is, if a color be mixed with a large proportion of white light, it will not be visible. Captain Abney has shown that the extinction of every color is effected by white light, which is seventy-five times brighter than the color. A pale wash of a pigment is not visible on white drawing paper.

When the colors of opaque substances are estimated by the tintometer, the comparison light is obtained from pure plaster of Paris carefully pressed in a small tray.

The colored glasses used in the tintometer are of three kinds, rose, blue, and yellow. Colored glass gives rise to its color through absorption. When a beam of white light falls on a piece of colored glass, part is absorbed and part is transmitted. On the screen is a spectrum of the blue glass, No. 16 according to the tintometer scale. It will be seen that there are three definite black bands, one in the orange, one in the yellow, and one in the green. These are called absorption bands, and are due to the fact that blue glass absorbs the rays of the spectrum which previously occupied the position of the black bands. The absorbed rays are probably converted into some other form of energy.

The color of colored glass is therefore a color which has been produced by subtraction of certain constituents from white light. I showed in the first experiment that if any constituent color be removed from white light, the residual light will appear of the complementary color.

I will now draw your attention to the three figures representing the curves of absorption of the three colored glasses. Absorption diagrams are usually represented by spectra with shaded bands of different depths to represent the absorption bands. It is almost impossible to represent an absorption spectrum in this way when any great degree of accuracy is required. We can more easily represent an absorption spectrum by a curve, the height of the curve corresponding to the degree of absorption. No substance is absolutely transparent to any of the rays of the spectrum. In all cases the absorption is only a question of degree. In the case of the diagrams representing the absorption of light by the tintometer glasses, the absorption by the rose glass is represented to 220° of the tintometer scale, that of the blue glass to 162°, and that of the yellow 207°. We could make the curves quite complete by examining an increasing series until the transmitted light was too feeble to affect the eye. A curve constructed in this way would show the exact proportion of the constituents of white light transmitted by a colored glass.

We have now to consider the cause of the difference in hue and shade of light when allowed to pass through several thicknesses of the same colored glass from that which it appears when transmitted through a single piece. If a colored glass or substance absorbed certain rays of the spectrum, and those only, it would appear of the same color in a thick layer as in a thin layer, because the thin layer would absorb these rays, and the effect of putting another thickness of glass in the course of the transmitted beams would be *nil*, as it could not affect any of the remaining rays of the spectrum. As I have previously stated, no substance is perfectly transparent to any of the rays of the spectrum, but there are substances which are opaque to certain spectral rays, and almost transparent to the remainder. These substances appear of nearly the same color in a diluted as in a concentrated solution, in a thick as in a thin layer. Chromate of potash is one of these substances, and it appears very nearly the same color in a dilute as in a concentrated solution.

THE ROSE GLASS.

The glasses of the tintometer therefore produce their colors as follows. Let us first consider the rose glass. If we take the weakest glass and examine it with a spectroscope, we find that the light is transmitted proportionately to the curve in Fig. 1, that is to

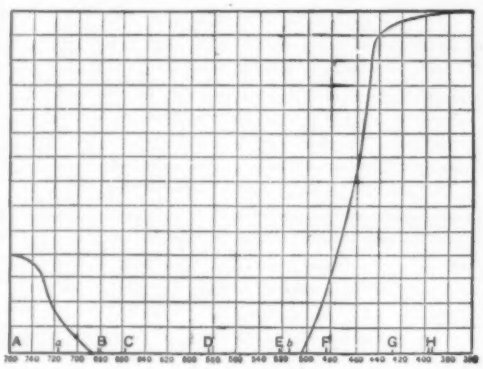


FIG. 1.—ABSORPTION CURVE OF THE ROSE GLASS TO 220°.

say, the green is most absorbed, then the violet, and so on. This glass will then correspond to the apex of the curve, and the resulting color will be that of light with certain constituents removed in the proportions represented by the curve. Total absorption only takes place at the apex of the curve. It is evident therefore that if we allow the light to pass through two pieces of this glass the second piece of glass can only act on those rays which have passed through the first. As the colored light absorbed by the second piece of glass is proportional to the heights of the curve, the absorption diagram of both combined may be represented by the curve with a portion of the apex removed. At the point of section there is total absorption. In this way by adding to the number of glasses we pass downward toward the base of the curve, the sections indicating total absorption becoming larger and larger, and the amount of light transmitted through the glasses smaller and smaller. From this it is evident that a feebly tinted glass transmits more red light than a glass of a much deeper shade. From the curve it will also be seen that the hue of the transmitted light becomes of a purer red as the number and depth of the glasses are increased, and the violet becomes absorbed.

Rose 22, when examined with the spectroscope, shows a dark absorption band, occupying two-thirds of the green. The violet is partially obstructed. The glass is almost transparent to the remaining rays of the spectrum.

When high combinations are examined, the hue of the transmitted light first changes to orange red and then to a pure red.

R. 22 + 21. Most transparent to red, orange, yellow, and yellow green; opaque to green and blue green. Transmits blue and violet partially.

R. 22 + 21 + 20. Most transparent to red, orange, yellow, and yellow green; opaque to green and blue green. Transmits a few blue and violet rays.

R. 22 + 21 + 20 + 19. Transmits red, orange, and yellow partially; opaque to rest of spectrum.

R. 22 + 21 + 20 + 19 + 18 + 19·5 + 18·5. Transmits red and orange partially; opaque to rest of spectrum.

R. 22 + 21 + 20 + 19·5 + 19 + 18·5 + 18 + 17·5 + 17 + 16·5 + 16 + 16·5. Transmits red partially; opaque to rest of spectrum.

It will be noticed in all the diagrams that the absorption bands at the red end of the spectrum, as represented by the curves, occupy positions nearer the center of the spectrum than they do in the corresponding spectra on the screen. This is due to the fact that, in a spectrum produced by a prism, the colors at the red end occupy less space than they should, having due regard to their wave lengths. The figures in the diagrams indicate the wave lengths of the various rays in millionths of a millimeter. The letters indicate the positions of the principal Fraunhofer lines.

THE BLUE GLASS.

This glass is a pure blue in its lighter shades, but the deeper shades incline to violet. In still deeper combinations the hue inclines to reddish violet.

Blue 20 shows a dark absorption band occupying the red orange, and another in the yellow. The remainder of the orange is nearly absorbed. There is an absorption band of medium depth occupying the central third of the green. The glass is almost transparent to the remaining rays of the spectrum.

In examining the lighter shades of this glass, the absorption bands occupying the red orange and the yellow are the first to appear. (See Fig. 2.)

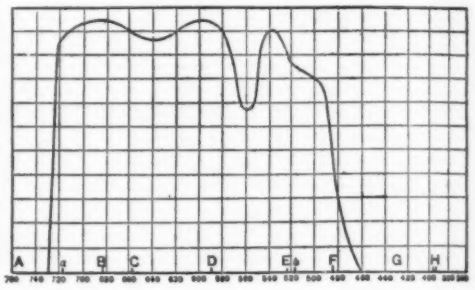


FIG. 2.—ABSORPTION CURVE OF THE BLUE GLASS TO 162°.

B. 20 + 19. Almost transparent to band of red, blue, and violet. Transmits yellow green and blue green partially; opaque to rest of spectrum.

B. 20 + 19·5 + 19. Almost transparent to band of red, blue, and violet. Transmits blue green partially; opaque to rest of spectrum.

B. 20 + 19·5 + 19 + 18·5. Transmits a band of red, blue, and violet partially; opaque to rest of spectrum.

B. 20 + 19·5 + 19 + 18·5 + 18 + 17·5 + 17 + 16·5 + 16. Transmits a band of red and violet; opaque to rest of spectrum.

The absorption is always in the same ratio, namely, that shown in the diagram, but as the other colors become absorbed, so do the red and violet rays preponderate, and so the color becomes reddish violet.

The great defect in this glass is that it absorbs the green to a very considerable extent. This in a great measure interferes with its utility in combinations.

THE YELLOW GLASS.

This glass in its lighter shades is a pure yellow. Its deeper shades incline to yellow green.

Yellow 16 absorbs the violet, but is almost transparent to the blue and the rest of the spectrum. (See Fig. 3.)

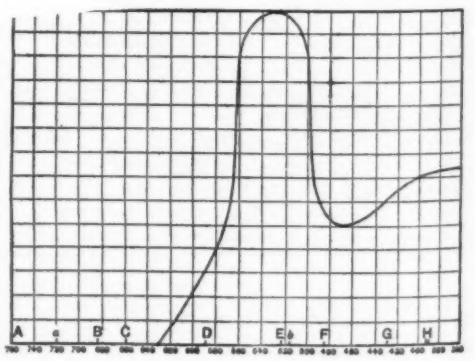


FIG. 3.—ABSORPTION CURVE OF THE YELLOW GLASS TO 207°.

Y. 16 + 15·5 + 14·5 + 13·5 + 12·5 + 12 + 11·5 + 11 + 10·5 + 10 + 9·8 + 9·6 + 9·4 + 9·2. Most transparent to orange, yellow, and yellow green; partly transmits green and orange red; opaque to rest of spectrum.

This glass is one of considerable utility. Though in the deeper shades the yellow green rays predominate, these are near the yellow, and so do not interfere with the practical usefulness of the color.

With regard to simple combinations.—B. 16 + Y. 16 = Green. Dark absorption bands are visible in the red orange and yellow. Absorption band of medium depth in the center of the green. Very little of the blue and violet can be observed. The yellow green is seen best. An orange band and the terminal band of red are also seen.

B. 16 + R. 16 = Reddish Violet. Dark absorption bands in the red orange, yellow, and central green.

* A paper recently read before the Society of Arts, London.

The yellow green is seen best. The remaining rays are partly visible.

R. 16 + Y. 16 = Orange. The blue and violet rays are absorbed. There is an absorption band occupying the central two-thirds of the green. Blue green rays partly visible. Almost transparent to rest of spectrum.

The spectroscopic composition of any combination may be ascertained by adding together the absorption bands as represented in the diagrams and deducting the whole from a complete spectrum. Mixture of the remaining rays gives the color of the combination.

It will be seen that the best glass for the purpose required is the rose, which chiefly affects the green of the spectrum. The worst glass is the blue, as the absorption is not confined to one portion of the spectrum, and a number of green rays are absorbed. From this it will be seen that it is not possible to obtain a very bright green by combining the blue and yellow glasses.

The inventor claims that any color may be matched with the instrument, and my experience confirms this. Colors, as, for instance, the aniline dyes, which are purer than those produced by the tintometer, may be matched in the following way: The color should be matched as nearly as possible with the glasses of the tintometer. When this has been done the sample color should be reduced by adding glasses of the complementary color to it.

For instance, supposing the sample color is a bright pure green, this should be matched approximately with blue and yellow glasses. Rose glasses should then be added to the color to be matched, until it is brought within the range of the tintometer colors. It will often be found that the addition of the complementary glass or glasses to any color will produce not only a change in luminosity, but also an alteration in hue. The reason of this is easy to comprehend. The yellow and blue glasses of the tintometer, when combined, make a green, because the yellow glass absorbs the whole of the violet rays, and so causes the blue to appear green, which is the color produced by mixing the remaining spectral rays.

Now, if this yellow glass be added to a blue, with the intention of reducing its luminosity, it will be found that the blue is not only reduced in luminosity, but that it has also become of a greener hue. This does not directly affect the record, but it does so indirectly, as will be explained shortly. The following example will show how, in practice, these matches are obtained.

A solution of methyl orange in a ¼-inch cell being the color to be matched. The color of this was orange. The nearest match in color was produced by R. 8·2 + Y. 48·5. The solution, however, was very much brighter. An exact match was made as follows: Methyl orange solution + B. 3·3 = R. 7·2 + Y. 48·5. It will be seen that when the blue was added one degree less rose was required.

With this and any other color-matching instrument there is a source of error which has to be carefully considered, and it is due to two factors: 1. That colors appearing exactly alike have not necessarily the same spectroscopic composition. 2. That the spectral composition of daylight varies from day to day, even from hour to hour.

As an instance of a color varying from these causes, let us consider a solution of chlorophyl which has been matched with a green, which, when examined spectroscopically, does not transmit any of the red rays. A solution of chlorophyl is transparent to a band of red at the end of the spectrum. If this match has been made at a time when the red rays were abundant, as at midday, the two colors would not match later in the day when the red rays were not so abundant. The red rays would be subtracted from one color and not from the other.

This objection might be overcome if a fixed standard light could be used. I made a series of experiments in order to ascertain what was the effect of this objection in practice. In order that there might be no complication from fading, I obtained a series of colored glasses, cut to fit the tintometer. The spectroscopic composition of glasses can be easily ascertained. I made a numerous series of experiments with red, orange yellow, pure green, greenish blue, light purple, and dark purple glasses.

I matched these glasses at different times of the day, and on different days. I matched them when the sun was shining and when it was raining or misty. There was a slight variation in the matches on different days, but not so great as I expected. On days which appeared similar in regard to the character of the light there was no appreciable variation. I think that, for practical purposes, this source of error might be disregarded, care being taken that the examinations are made under as nearly as possible similar conditions of light.

THE VALUE OF THE STANDARD.

The inventor has employed for a standard a glass very faintly tinted with color, and all the other glasses of deeper hue are multiples of this standard. For practical purposes the standard is convenient, and within certain limits gives accurate results. An objection to this method of standardizing is that a portion of the spectrum having been absorbed by a glass of a given color, any glass of a deeper shade of this color must absorb other rays than those absorbed by the first glass. The combination of a number of glasses of a given hue therefore does not necessarily give rise to a deeper shade of this hue, but may produce a color of quite a different hue.

This may be admirably illustrated with a solution of chloride of chromium. A thin layer of this solution appears green, but a thick layer appears red. On examining the solutions spectroscopically, the reason of this is evident. A thin layer of chloride of chromium is more transparent to the red rays at the extreme left of the spectrum than to any other part, but the predominance of the green rays causes the color to appear green. When a thicker layer of the solution is used, the green rays, as well as the rays absorbed by the thin layer, are absorbed, and so the color appears red. With the tintometer glasses the deeper shades of the blue incline to violet, and the deeper shades of the yellow incline to yellow green. In each case this is more marked if several glasses be used in combination.

Most persons, on looking at the diagrams of the absorption of light by the colored glasses, and noticing how irregular the curves are, will wonder how it is that the inventor, with one kind of colored glass, has been able to obtain a series which has a nearly uniform hue. As I have previously stated, the deeper shades of yellow incline to yellow green, and the deeper shades of blue incline to violet. The change in hue is scarcely noticeable. The rose glass appears of one definite hue throughout.

This is due to the limitation of our color perception. A spectrum appears to be made up of six definite colors, which pass by innumerable gradations into each other. Therefore, it has been concluded that the number of colors is innumerable. This is an illusion, which is heightened by the knowledge that the colors in the spectrum should be practically innumerable in accordance with the wave lengths of the different rays of light. If we examine the spectrum in another way, all colors but the one under observation being excluded, we find that it is apparently made up of a series of monochromatic bands. These monochromatic bands differ in size according to the acuity of color perception of the observer. A person with acute color perception sees differences in a band which appears monochromatic to another person. These monochromatic bands, even for a person with the acutest color perception, are very large in comparison with the units of the physical series, that is, rays of light of a definite wave length. Here is a spectroscope which I have had constructed for ascertaining the size of these monochromatic bands. If, for instance, a monochromatic band in the green is being looked at, the observer cannot say on which sides the blue and yellow are situated. These monochromatic bands I have designated absolute psychophysical color units because they form the units of the psychophysical color series. As we are now only concerned with color perception in its bearings on the tintometer, I will refer those who wish to pursue the subject further, to my recently published work on "Color Blindness and Color Perception."* If the hues produced by the mixture of red and violet be added to the spectral series, then all known colors will correspond in hue to some point of this series. If we divide this series according to the number of absolute psychophysical color units seen by a person with normal color perception, we see that colors may differ considerably, and yet match perfectly, because both are included in an absolute psychophysical unit. It is evident that if we divided a monochromatic patch into a number of different portions, those portions would all match perfectly, though differing in their physical characters.

This fact makes the instrument of much greater utility than would otherwise be the case. The hue of the glasses practically corresponds to one psychophysical unit throughout the series. Though this fact increases the practical value of the instrument, it militates against its use for the scientific registration of color, when we wish to record, as nearly as possible, the wave length of the observed color.

We have also to consider the influence of the other rays which are transmitted by a glass, upon the color which the glass appears. With three spectral colors, red, green, and violet, we can match all colors: red and green, when combined, form yellow; green and violet make blue. I have already mentioned the fact that white is formed by the union of the complementaries. Therefore the transmission of rays other than those peculiar to the color of the transmitted light either intensifies this color or dilutes it with white light.

The instrument is one which would be very useful to those who wish to continually reproduce objects of a given hue, as, for instance, manufacturers of colors. Its value, from a practical point of view, would be considerably increased if glasses were employed which had, as nearly as possible, the same spectroscopic composition as the substance to be matched. For instance, if a red substance is required in a certain manufacture, and it is necessary to have it always of the same hue, then a series of red glasses, having as nearly as possible the same spectroscopic composition as this substance, should be employed. This will, in a great measure, eliminate the source of error produced by the varying spectroscopic composition of daylight. The instrument might also be considerably improved if it were possible to employ a blue glass which was perfectly transparent to the green rays.

I have employed the instrument to estimate the difference in the perception of color in the two eyes, and it shows admirably how a color appearing yellow to one eye may appear yellow green to the other.

In conclusion, I am of opinion that the instrument is one which affords every one who is interested in recording color for some definite, practical object a simple means of doing so. The colors of glasses have a stability which is not possessed by pigmentary colors. It is obvious that the admirable method of matching colors which has been devised by Captain Abney, and is described in his book on "Color Measurement and Mixture,"† cannot be generally employed for practical purposes on account of the expense of the apparatus and the knowledge required in using it. The tintometer can be used by any one who has carefully read the instructions given by the inventor. I thank you for your kind attention, and hope that I have succeeded in showing the range of utility posssessed by this instrument.

Captain Abney said Mr. Lovibond had perfected this admirable instrument in a manner which not only reflected the greatest credit on him, but showed the scientific character of his mind, though, as he understood, he had not had a scientific training. It was quite true he believed, as stated in the paper, that if you had two or three glasses together you could tell the character of the light by deducting the absorption of each glass from white light, and mixing the remainder; but in order to do that, it was necessary, on this plan, that each individual glass should be measured, which would be a work of no small labor. Mr. Lovibond had taken as his standard the minimum color, and his contention was that for scientific purposes it was rather the maximum which ought to be standardized—for this reason. If you put twelve No. 16 glasses together, though he was quite sure they would not differ appreciably, and if you had the total absorption, you could easily calculate that of each one; but when you came to take the absorption spectrum of a faint color, the errors you might make were so enormous that, when multiplied by twelve, they would make the readings untrustworthy. A great many yellow glasses together gave orange, and from several blue glasses you got a very different color from that of a light-tinted glass. On what system, therefore, was it suggested that the absorption spectrum should be deducted from white light so as to get a scientific measurement of colors? Dr. Edridge-Green said two colors which differed considerably in wave length might yet match perfectly, because they were both included in one psychophysical unit. It might be a matter of opinion or of experiment, but he certainly could not accept that statement, which seemed to him erroneous because he personally could distinguish any slight variation in the color of the spectrum which lay, he thought, well within the psychophysical unit as defined. He could see plainly that one part of the green patch shown on the screen was yellower than the other. With the instrument which he had shown there on more than one occasion, the minutest difference in the position of the slit placed in the spectrum could be detected. If you could divide the spectrum into 100 parts, you could tell each one from the other. In looking at a rather impure spectrum, at first glance, he only saw three colors—red, green and violet; and when he came to examine it, he found an infinity of colors. He therefore could not indorse the statement that you could not distinguish one color from another if they were situated close together, and his opinion was founded on experiments which numbered thousands, and had been going on many years. As to the glasses, he had already said that this instrument was very valuable, but he could not sanction Mr. Lovibond's heresy that there was any combination of rays in one kind of light more than in another. The great thing to aim at was to have a material perfectly free from banded absorption, which for scientific purposes was a great drawback. The blue glass appeared to be cobalt, but there were other blues which were free from those bands of absorption in the red end; and for scientific purposes it would be preferable to use a glass having general absorption rather than one with a banded absorption. The normal light from white fog was very interesting. The search for a normal or standard light had gone on for some years, but for his own purposes, and for scientific work, he found nothing to equal the crater of the positive pole of the electric arc. It was always a uniform temperature, and was always equally white, which could be proved thus: Take a shortish spectrum, and put in two slits, one in the green and the other in the violet; mix the two lights together in such proportion as to form white, and you might watch alongside of it the white light undecomposed. Put any carbons you liked into the lamp, there would be no variation, showing that the proportion of green to violet was the same in both. To that standard all lights and all colors might be referred. He was surprised to hear that distilled water was yellow and green. A few years ago, he investigated the absorption spectra of colorless fluids in the ultra red by means of photography, which had no personal bias, and registered its own results, so that there could be no mistake, and distilled water he found anything but yellow. He had a tube six feet long and no ultra red light passed, very little red, slight yellow, and plenty of blue; so that distilled water in its purest form certainly had a blue tint. He did not throw any doubt on Mr. Lovibond's observations, but on the purity of the water he used. The water from the gravel well seemed to bear out the conclusion that pure water would be a blue color.

Mr. Lovibond said there might be impurities in the standard glasses. Even supposing that the impurities were not self-correcting, he did not think they could be so great as to create the difference between the two sets of observations. The water he used was carefully distilled from glass, but you could make such water look any color you liked, by illuminating it with light of that color. If you looked at it with light from a blue sky, you had a beautiful blue color, while, in the morning's light, you get a reddish tinge; in fact, the visual color changed with the light, while the measured color remained constant. There was always a danger of mixing up the measurement of the object with the light it was viewed by. That was why he did not like to rely on measurements made by intense light. No definite statements of visual impressions could be made unless the light employed was quoted.

Dr. Thorne said he had used this instrument for some time in his laboratory for estimating the colors of oils, glass, and so on, and found it very useful for registration and comparison. It gave results which were not to be obtained by any of the easily utilizable forms of colorimeters. From a scientific point of view, as Captain Abney had said, an intense color would be the best unit, but for ordinary purposes it was necessary to deal almost entirely with low tint colors.

Dr. Edridge-Green, in reply, said Captain Abney had answered the objection raised by Mr. Lovibond with regard to the light, and he need only add that it was desirable to choose lights as nearly as possible of the same character. The method he had described, of measuring the absorption curve, was the same as that employed by Captain Abney. For the yellow, he took about twenty-two glasses, which gave the highest point, 207°. One could go on adding glasses until all the light was excluded, and thus get a complete curve. It would be very difficult to measure with the spectroscope faintly tinted glasses. With regard to the psychophysical units, the patch on the screen was only approximately monochromatic, but in looking at a pure spectrum, he could see a very large portion which appeared absolutely monochromatic, as did the patches Captain Abney had showed him, which contained a large number of wave lengths. He had not succeeded in seeing any more colors in a magnified spectrum than in one produced by a good spectroscope. He therefore ascribed this limitation to a limitation in perception, and he fouud this to differ in different persons. Some could see very minute deficiencies, but even then they saw a unit which corresponded to a large number of wave lengths.

Captain Abney said with his instrument you could make the slit as fine as you liked, for instance, as the difference between the two D lines. The spectrum could be made as pure as you liked by closing first the slit of the collimator, and secondly, the slit in the spectroscope. If you had a spectrum of 5 in. length, and

* "Color Blindness and Color Perception." International Scientific Series. Kegan Paul, Trench & Co., 1891.

† "Color Measurement and Mixture," by Captain W. de W. Abney, F. R.S., published by the Society for Promoting Christian Knowledge, Northumberland Avenue, W. C.

made the slit 0·01 in., it would not be difficult to calculate within what difference of wave length you got a different color.

Dr. Edridge-Green asked if Captain Abney could distinguish a difference of color between the two D lines. To him they were absolutely monochromatic.

Captain Abney said the only way to compare two colors was to put them side by side in a patch, and he had never done that with the light of the two D lines. You might call a line any color you liked almost when dim; there must be a certain area, or you could not distinguish it. You would not see any yellow in the sky through a pocket spectroscope, because your vision was confined, but directly you took a large spectroscope and pointed it in the same direction, the yellow appeared. It was a question of size as much as anything else.

Dr. Edridge-Green admitted that entirely, but said different persons had different perceptive powers. One would see yellow where another would not. In the case mentioned where the yellow was not seen, the observer was reduced to a condition of perfect perception; in other words, he saw as if he were partially color blind. Orange was the first to go; then blue, then yellow, then green. He did not think a normal sighted person could succeed in reducing his perception below the three primary points of difference—red, violet and green; but by reducing the light you could cause yellow, or blue, or orange to disappear. However you magnified the spectrum, you saw no more colors and no less. With defective light you might see five, four, or three, instead of six. He had never succeeded in seeing the seven which Newton described; but there were a few persons who did, and they described them exactly as Newton did. It was only in that sense he used the term psychophysical units.

The chairman, in proposing a vote of thanks to Dr. Edridge-Green, said the deep blue color of water treated by Clark's process could be very well seen near Caterham, in the tanks of a local water company, where this process was adopted. It had always appeared to him to be analogous to the blue of the sky, and to be due to the same cause, namely, the presence of very fine particles, arising from the precipitation process, which had not sunk to the bottom.

A SHORT HISTORY OF BRIDGE BUILDING.*

By C. R. MANNERS.

THE art of bridge building dates back to a very early period, long before the Christian era. The importance of the art can scarcely be overestimated, since bridges form the connecting links of communication between villages, towns, and cities, over rivers and arms of the sea, the passage of which, by the old system of stepping stones or ferries, was often dangerous and sometimes impossible. Possibly the first form of bridge was that of two struts, hinged at the apex, and provided with means by which they could be made to move alternately one before the other. When the distance to be spanned became too great for man's legs thus to stride over, he would lay a big stone in mid-stream, and so form an intermediate pier for his walking bridge, what we call stepping stones. It may be that he took a hint from a fallen tree, and threw a piece of wood, a tree trunk, or a long flat stone, across the stream at some narrow point, or, if the stream were too wide to do this in one span, he would perhaps take advantage of some rock or large bowlder in mid-stream, and so form his bridge of one or more openings. From this he would naturally begin to build intermediate piers of such heavy rough stones as he was capable of placing in the required situations, and either form his platform of rough timber or by laying large flat stones across from pier to pier. In course of time the arch came into use, and all the various forms we now have of the arch, beam, etc.

For the purposes of this sketch we shall find it convenient to divide bridges into four classes.

1. Suspension.
2. Pontoon or floating.
3. Arches.
4. Beams or girders.

Some bridges, however, are not very easily classified, but they must take their chance of being mentioned under one of the above classes.

Suspension Bridges.—In all forms of suspension bridges, the supporting material, that is, the rope or chain, is extended by the stress due to the load. The means of suspension may be of ropes of hide or vegetable fiber, iron or steel wire, or of links pinned together to form a chain. From very early times light suspension bridges of a primitive description seem to have been in use in South America, India, China, and other places. A very simple form has long been in use in Thibet and Peru. Two ropes are stretched side by side across the river or gorge, and these carry a rough platform or roadway. In India the suspension bridges used by the natives are called "tarabita." They consist of a rope made from strips of hide or fibers of plants, stretched across the river and fixed to posts or trees on the opposite banks. On this rope a basket is suspended by loops, in which the person who wishes to cross the river takes his place, and is then hauled across by a smaller rope from the opposite bank. Humboldt describes a suspension bridge over the River Chambo in Quito (Ecuador in South America), the main ropes or cables of which are four in. in diameter, laid over frames of timber on each bank, and secured to posts driven into the ground. Over these ropes is laid a roadway. The span is 131 ft., and, as may well be imagined, it is somewhat difficult to walk over the bridge owing to the oscillation. There is, however, some kind of side guard to prevent passengers falling off. Fig. 1 is a sketch of such a bridge, at Penipe, copied from Humboldt. Major Ramel mentions a suspension bridge over the Sampoo River in Hindostan, with a span of 600 ft. From a very early date the Chinese seem to have constructed suspension bridges of considerable magnitude. The most celebrated seems to have been in the province of Junnan, constructed in the year 65 A. D. Kircher, the missionary and traveler, describes this bridge as follows: "It is not raised with the cementing of vast stones or brickwork, but with iron chains fastened at either end to rings or hooks, so placing the bridge to beams above; there are twenty chains, and every one consisteth of twenty perches; many persons passing over together, the bridge moveth hither and thither, possessing the passengers with giddiness and fear of the ruin and fall of the bridge, so that I cannot sufficiently admire at the dexterity of the Chinesian architects, who durst undertake so many and difficult works for the conveniency of passengers."

Fig. 2 represents a native bridge in the Caucasus, 80 ft. span, the cables of which were made of grape vines. These cables have three vines in each strand, and are secured to trees on the opposite banks of the river. The footpath is of narrow planks suspended at intervals from the cables. It is said that the invention of the suspension bridge was imported from China or India, and it does not seem to have been introduced into Europe until about the close of the sixteenth century. It is probable that the discovery and use of the arch retarded its adoption until the practical limits of the arch were reached, and it was necessary to cast about for a method of construction for bridges on a cheaper plan, and where the arch was, at that time, impracticable.

In a book entitled "Papirii Massoni descriptio Fluminum Galliæ qua Francia est," Parisiis, 1678, there is a notice of three hanging bridges over the River Charente. Drewy, on the authority of Davalia (historian at the end of 16th and beginning of 17th centuries) states that Charles IX. used bridges of cordage at the siege of Piretius, toward the close of the 16th century, which is perhaps their first introduction to Europe.

The first suspension bridge in England was erected in 1741 across the Tees at Middleton. It was 70 ft. span, and erected for the use of miners. It consisted of two common chains stretched across the river and fixed into the rock at each side. These chains carried the footway.

In 1796 a Mr. Jordan took out a patent for a system of bridge with a suspended roadway, but as the members from which it is suspended are evidently in compression, it has been wrongly called by some a suspension bridge, and further notice of this patent is postponed runtil we come to beams, etc., as it appears to partake of the pinciple of the bowstring.

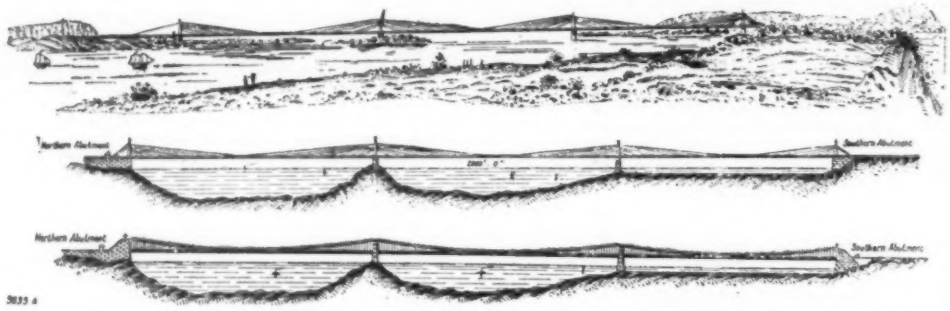
In 1816 a suspension bridge of about 112 ft. span was erected at Galashiels, and another about the same span over the Tweed at Peebles. So long ago as about the year 1740 there seems to have been a proposition to bridge the Forth, but no particulars as to the site or design seem to be now forthcoming; but in 1818 we find Mr. James Anderson, civil engineer, Edinburgh, come forward with designs for crossing the Firth of Forth at Queensferry, by means of a chain bridge. Three designs were given for this bold project. The clear height above water was to be either 90 ft. or 110 ft., the main spans 1,500 ft. or 2,000 ft., and the estimated cost from 175,000*l.* to 205,000*l.* (Figs. 3, 4, and 5.)

The introduction into England of the improved system of long bar links has been attributed to Sir Samuel Brown. Telford seems, however, to have given attention to this system in 1814, when experimenting for the proposed Runcorn Gap Bridge, and he would seem to have the prior claim, as it was not until 1818 that Sir Samuel Brown made his model of 100 ft. span capable of carrying a carriage and horses and adapted for general traffic. In the succeeding year he constructed upon this long bar principle the Union Bridge over the Tweed, near Berwick, the span of which was 450 ft. between the supporting towers of masonry. The chains are rods of round iron 2 in. in diameter with a deflection of 30 ft. He subsequently built one at Dryburgh and one at Montrose (432 ft. span), completed in 1829, the chains of this being of flat bars of wrought iron. (Fig. 6.)

The crossing of the dangerous ferries over the Conway and Menai Straits had long been a subject occupying the attention of engineers, and in 1819 Telford commenced the construction of his great Menai Suspension Bridge. In 1776, Mr. Golbourne had proposed an embankment with a bridge in the middle. In 1785, Mr. Nichols suggested a wooden viaduct with drawbridges, and still later, Mr. Rennie proposed a cast iron bridge. In 1810, Telford submitted alternative designs, one being an arch of 500 ft. span, and for the erection of this he proposed the then novel idea of suspending the centering from above, instead of supporting it from below. All these designs, however, were rejected. In 1814, Telford, being consulted as to the construction of a bridge over Runcorn Gap, near Liverpool, had a series of experiments made as to the tenacity of wrought iron bars. These tests he afterwards repeated, and when in 1818 he was again consulted as to the crossing of the Menai Straits, they were of immense value to him in designing his great suspension bridge, of which a short description may be given here to accompany the sketch, Fig. 7. The center span is 580 ft. and the deflection of the chain 42 ft. The two side spans are 260 ft. each. The roadway is 100 ft. above high water. The masonry towers are carried 50 ft. above the roadway, and are connected with the shore on each side by stout arches of 52 ft. 6 in. span. There are 16 main chains, each 1,770 ft. long, and arranged in sets of four each, suspended above each other. Each chain is made up of bars 10 ft. long by 3½ in. by 1½ in., five of these

FIG. 1.—BRIDGE AT PENIPE.

FIG. 2.—OLD BRIDGE IN THE CAUCASUS.



FIGS. 3, 4, AND 5.—ANDERSON'S DESIGNS FOR SUSPENSION BRIDGE OVER THE FORTH.

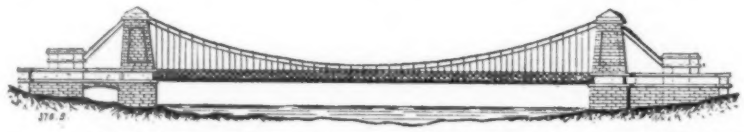


FIG. 6.—SIR SAMUEL BROWN'S SUSPENSION BRIDGE AT MONTROSE.

FIG. 7.—TELFORD'S MENAI SUSPENSION BRIDGE.

* From *Engineering*, London.

bars, side by side, forming one link of the chain, connected by plates and pins, and securely anchored in tunnels driven into the solid rock. The central portion of each chain was put together on a large raft 450 ft. long and 6 ft. wide, and then floated in between the piers. One end was secured to the land end of the chain, which hung down the face of one of the piers, and the other was attached to strong ropes, connected with capstans, and so hoisted up to their final position.

Telford had an anxious time of it, there not having been any previous great work of the kind as a guide, and great was his thankfulness when he saw the first chain safely in its place. Three of the workmen were foolhardy enough to scramble across this chain, which was only 9 in. wide. The suspended weight of the main span is 644 tons. The bridge was completed in 1826 at a cost of about £120,000, including approaches. The Conway suspension bridge was constructed by the same engineer and at the same time as the Menai bridge.

The success of this type of bridge construction led to the erection of many other large suspension bridges; one at Vienna, over the Danube, 334 ft. span, completed in 1828, in which the engineer, Herr von Mitis, used steel bars for his chains; one at Fribourg, in Switzerland, 870 ft. span, by M. Chaley, who used chains composed of 4,224 separate wires, a very general practice on the Continent; one at Pesth, of 666 ft. span, built in 1839–49; one over the Thames near Charing Cross, 676½ ft. span, since removed to make way for the railway bridge, and re-erected at Clifton. The first introduction of wire rope as the suspending member seems to have been in 1823, by M. Seguin, of Lyons.

In 1852 the great Niagara Falls bridge was commenced, Mr. Roebling being engineer. It has a single span of 821 ft. 4 in., and is 245 ft. above the level of the water. The superstructure may be described as a great hollow rectangular box 18 ft. deep and 24 ft. wide, on the top of which runs the railway, while the bottom carries a carriage roadway. Both floors are of timber beams, connected at the sides by timber uprights 5 ft. apart, with wrought iron diagonal bars between. The upper floor is suspended at intervals of 5 ft. from two wire cables 10 in. in diameter, and composed of seven strands, each containing 520 wires. The lower floor is suspended from similar cables, having, however, 10 ft. greater deflection than the upper one. There are also 64 diagonal stays of wire rope 1⅜ in. in diameter, extending from the saddles on the towers to points along the roadway, and 56 stays from the underside of the bridge, well anchored into the rock near the abutments. The bridge was completed in 1855 at a cost of about £80,000. (See Fig. 8.)

Suspension bridges are, however, not suitable for heavy railway traffic, and it was found necessary to limit the speed, in the case of the Niagara bridge, to three miles per hour. It was stated by Mr. Stevenson that when a train crossed a suspension bridge formerly standing at Stockton, and about 300 ft. span, a wave 2 ft. high rose up in front of the engine.

Mr. Roebling has also constructed a very fine suspension bridge over the Ohio River, in Cincinnati, the center span of which is 1,057 ft. and the floor 103 ft. above the water; and in 1883 the Brooklyn or East River bridge, at New York, was finished with a center span of 1,595½ ft. and two end spans of 930 ft. each. In the center of this bridge is a raised footway 15 ft. wide; on each side is a line of railway, worked by endless ropes, and outside of all are carriage roads.

Various systems of applying the suspension principle have been adopted, among which was that of Dredge some sixty years ago, which differed from the ordinary suspension bridge, inasmuch as the suspending rods were inclined, and in the use of a lower member. These bridges are somewhat stiffer than the ordinary suspension bridge. Many bridges of this type were erected, among them that over the Spey, illustrated in Fig. 9. The Ordish system is a modification of the above.

Floating or pontoon bridges, of one kind or another, have been used for the passage of rivers or arms of the sea from a very early period. The supporting medium, or pontoon, is formed of boats, casks, leather bottles, or inflated bladders, or any other convenient or suitable material; the roadway is generally of planks supported by the pontoons. The earliest bridge of the kind of which I have been able to find any mention is that used by Cyrus, King of Persia, about the year 538 B. C. In this bridge the pontoons are said to have consisted of stuffed skins. Darius, King of Persia, threw bridges of boats across the Bosphorus and the Danube, in his war against the Scythians, about 513 B. C. We have no detail of their construction, but they must have been pretty strong, as he is said to have taken an army of 700,000 men over them. The architect or engineer of this bridge was Mandrocles, of Samos. Xerxes, King of Persia, had a bridge of boats constructed, 481 B. C., across the Hellespont, about a mile in length. This bridge has been described as being constructed between Sestos and Madytus, in the Chersonese of the Hellespont. The Phenicians used a cordage made of linen and the Egyptians used the bark of the biblos. A great storm destroyed this bridge, which so enraged the king that he ordered the heads of the engineers to be cut off, 300 lashes to be given to the sea, and a set of strong fetters to be thrown into it. Having administered this punishment, and fettered the unruly sea, he reconstructed his bridge on a double line of boats, 360 on the side next Euxine Sea and 313 on the Hellespont side; the former were placed transversely and the latter in the direction of the stream or current, to diminish the strain on the cables. These boats were secured on each side by anchors. Three openings were left for the passage of light boats. The cables were of white flax and biblos or papyrus, two of flax to four of biblos, united and all of the same thickness. They were laid from shore to shore and strained tight by wooden capstans. A cubit of cable weighed a talent. Timbers were laid across the cables and secured to them; these were floored over and the roadway formed. A fence was erected along each side to prevent the horses looking over into the sea. The Greeks employed a bridge of boats in crossing the River Tigris, about 400 B. C., in their retreat from Persia.

Alexander the Great, when on the march, occasionally carried along with his army a kind of boat divided into portions, and so made that it could easily be put together for crossing rivers. To enable him to cross the Oxus with his army (about 327 B. C.), he is said to have constructed rafts, made of the hide tents of the soldiers and stuffed with dry hay or straw, all the river boats having been burnt. Xenophon describes a similar method as used by him in his march through the desert, when he came to Carmandi, on the Euphrates. Herodiam, Lucanus the Roman poet, and others about the beginning of the Christian era, mention the use of casks by the Romans to support rafts for the passage of armies. Vegetius also mentions that it was customary for the Roman army to carry with them small boats made from the hollowed-out trunks of trees, with planks and nails and ropes, so that a bridge could be quickly constructed.

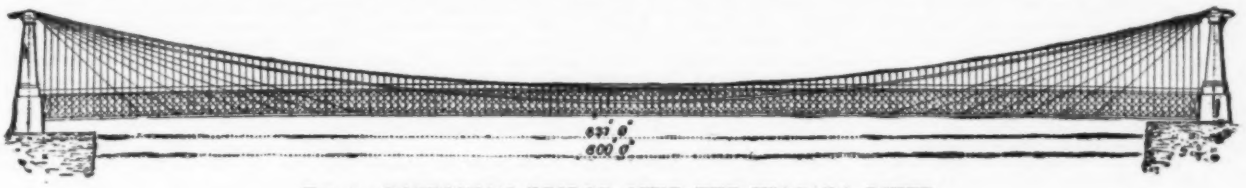


FIG. 8.—ROEBLING'S BRIDGE OVER THE NIAGARA RIVER.

In the fourth century A. D., the Emperor Julian used bridges of boats to cross the Tigris, Euphrates, and other rivers. These were formed of skins stretched over osier frames.

Coming down to more recent times, the Germans in the seventeenth century constructed pontoons of timber frames covered with leather, and the Dutch used similar frames covered with tin. The different forms and varieties of material used from time to time for pontoon bridges have been numerous. Some of the pontoons are open like an undecked boat, others are decked over, and others again are much in the form of cylinders. It is claimed for the closed or decked form, that they cannot be submerged by the river, and that only by too great a weight being put upon them can they be sunk. Among its disadvantages may be mentioned that it is difficult to keep water tight, and cannot be used as a row boat if occasion required.

During the Peninsular War, the British followed the custom of Europe and used the open form, but afterward abandoned it, because if large it was inconvenient to transport, and if small it was only useful in small streams, being liable to fill and sink. These pontoons were placed at about 12 ft. 6 in. apart, and the width of roadway was about 10 ft. General Colleton designed the first substitute for the open boat. His pontoon was cylindrical, with conical ends, and made with wooden staves like a cask. General Pasley followed with a pontoon like a decked canoe, with pointed bow and square stern. These pontoons were made of light wooden frames covered with coppered sheets, decked with wood, and divided into water-tight compartments and supplied with the necessary apparatus for pumping out water. One complete bay, or in other words, one pair of these pontoons, with their due amount of roadway, weighed about 2,103 lb. Blanchard's pontoon followed, and was used in the British army for some time during the time of peace. This was a cylinder cased with tin and with hemispherical ends, one bay weighing 1,500 to 1,600 lb. It was, however, experimented upon and abandoned as likely to break down in time of war. British engineers seem to have concluded that the open form of pontoon, to which Continental nations had adhered, are the best. Captain Fowks has invented a folding pontoon, or boat, constructed with sliding ribs and covered with waterproof canvas, so that for transport it will close up like an accordion. The central interval is 10 ft. 7 in., the width of roadway is 10 ft., while one pontoon and one bay of superstructure weighs about 1,250 lb. It is not, I believe, altogether satisfactory, being rather short in its supporting power. Colonel Blood is, I believe, the inventor of the open form with decked ends and the sides partly decked where the rowlock blocks are fixed. The central interval is 15 ft., width of roadway 10 ft., and the weight of a single bay is about 2,300 lb. In America, india rubber has been used instead of the skins, etc., employed by the Greeks and Romans, in obtaining the floating power. Floating bridges were not, however, confined purely to military purposes, nor yet are they always temporary constructions. A very primitive bridge, of early times, for crossing wet, marshy grounds, was formed by tying bundles of rushes together and laying them at intervals on the surface to support boards or planks.

In Africa floating bridges have been constructed of trees and bamboos bound together and forming a continuous and flexible roadway, which would rise and fall with the river (see Fig. 10). They are, however, generally carried away by every large flood, and have to be frequently renewed.

There is a bridge of 130 boats, joined by strong iron chains upon which are laid the timber beams and planks that form the roadway across the River Kautcheou-fou, in China. In this bridge two or three boats are removable to allow of passage of river traffic, and it also carries the custom house, which is built upon it. On the river at Ning-po, in the same country, there is another bridge of boats, also so constructed that one of the boats and roadway can be slipped out to allow of the passage of river boats.

At Rouen a pontoon bridge was constructed to take the place of the old Roman bridge which had previously existed there. It is about 300 yards long. The boats are strong, and firmly moored with chains. The roadway is paved with stone in the same manner as a street. There are also floating bridges at St. Petersburg, Presburg, Coblentz, Seville, and other places. In 1865 one was constructed at Carlsruhe 1,190 ft. long, and of this 768 ft. are supported on 34 pontoons, each 65½ ft. long by 12 ft. wide. This bridge carries both a railway and carriage road.

Many years ago Mr. George Stewart, of Port Hope, Canada, constructed a floating bridge across a swamp and river between Lake Scugog and Sturgeon Lake. Carrying out the idea of the corduroy roads, he con-

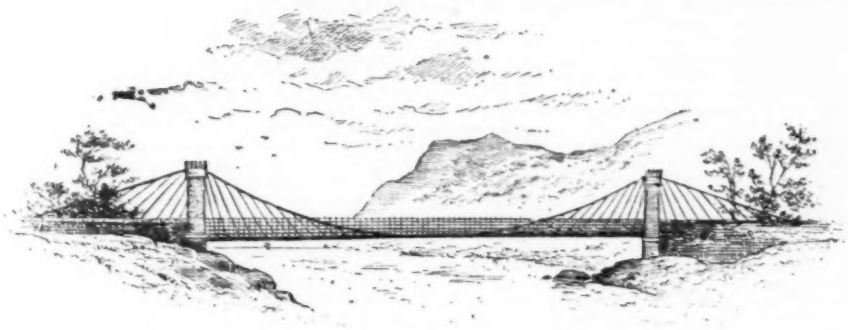


FIG. 9.—DREDGE'S SUSPENSION BRIDGE OVER THE SPEY.

FIG. 10.—FLOATING AFRICAN BRIDGE.

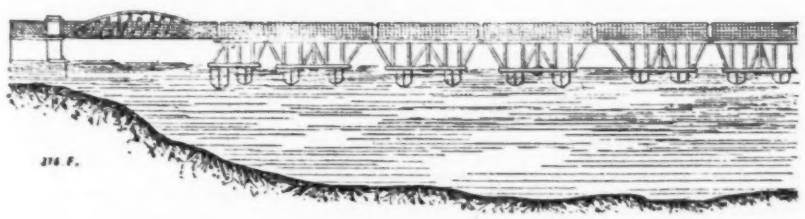


FIG. 11.—HOOGHLY PONTOON BRIDGE.

structed a bridge of about three-quarters of a mile in length. Rafts were formed of flatted timber 30 ft. square, connected by six or seven longitudinal beams on which transverse pieces were laid forming the roadway. The rafts were chained together and anchored to large bowlders in the water.

Many of the great rivers of India are crossed, on the main roads, by floating bridges. Of these I will only mention the great Hooghly Pontoon Bridge (see Fig. 11). The necessity for a bridge over the Hooghly at Calcutta, to connect that town with Howrah, on the opposite bank, became imperative. The great expense of a fixed bridge, the time it would require for construction over the deep and rapid river, with a shifting bed, the risk of accident by breaking adrift of shipping in cyclones and storm waves, gave the preference to a pontoon bridge, although it was thought impossible by many, owing to the great floods and "bores," and the bad holding of the silt and sand. The designs were prepared in 1868, and adopted by the government, and the work was commenced in 1873 and the bridge opened in 1874.

This bridge is 1,530 ft. long, and the total roadway is 62 ft. wide. It is carried on twenty-eight pontoons, each 100 ft. long by 10 ft. beam, coupled together in pairs by timber sills bolted to the decks and forming the bottom members of the trusses after mentioned to secure stability. They are rectangular iron boxes, with rounded bilges and wedge-shaped ends, and divided into water tight compartments, and securely anchored fore and aft. Four longitudinal wrought iron girders, 16 ft. apart, raised by timber trusses, at a convenient height above the water for ordinary boat navigation, support joists, 13 in. by 6½ in., placed 2 ft. 4 in. apart, and these carry the planking of roadway. Adjusting ways are arranged at both ends of the bridge for connecting with the land in similar manner to what we see used on floating landing stages. Arrangements are made by which a portion of the bridge can be bodily removed for the passage of large ships. This structure was the first and, so far as I am aware of, the only bridge of its kind elevated above the water to give headway for the ordinary river traffic, and, as it is one of the latest and most important of its kind, it forms a good termination for this section of the subject.

(To be continued.)

CONSTRUCTION AND REPAIR OF COUNTRY ROADS.

AT the road convention held recently in Trenton, N. J., a paper with the above title was read by Mr. James Owen, of Montclair, an engineer of wide experience in the construction and maintenance of highways. This paper, given in the *Engineering News*, is valuable from the many practical hints contained in it:

Mr. Owen commenced by saying that the three primary questions to be answered were: How to get the money to build roads; how best to lay out the road, and finally the proper way to build it. The question of finances was beyond the speaker's province, and the second point was hardly before a convention which had for its object the improvement of existing roads, and so to this latter point he directed his remarks, as follows:

Before going into the question of material for construction, it would be well properly to consider two or three points inherent to good work and applicable to all road construction. These are: The determination of grade, drainage and the finished shape of the road; and it may be safely said that no good and successful road work can be accomplished without a proper consideration of these three important items.

As to grade, it may be asserted that no road should ever be built on a level grade; and in my experience no grade should ever be less than 6 in. in 100 ft., as much more as you can possibly get, up to 12 in. in 100 ft., which is probably the most suitable grade for highways and gives a free and proper flow of the surface water from and off the road itself. Wherever water stands in a roadway of any kind (except of course city pavement), it has a tendency to disintegrate the material of which it is made, making it soft and easily influenced by the travel upon it. By a proper grade to your road you eliminate one source of trouble, namely, standing water. The extreme steepness of roads is of course dependent upon its location. A grade of 4 ft. in 100 ft. is the limit of good, easy traveling, and anything steeper than 10 ft. in 100 ft. should not be allowed, and that grade should only be permitted in exceptional circumstances. The custom of having grades of 13 to 15 ft. in 100 ft. in mountain roads is a bad one, and is due to the haste the originators had to get there. But in all establishments of grade make the standard limits between 1 and 4 ft. in 100 ft., and you will always have satisfactory results.

Incident to the grade of the road is the shape of its finished surface, known generally under the name of its crowning or rounding. Good judgment and experience are more required on this one point than in any other question of road building. If the road is too flat, the water will not run off properly and ruts are formed. If there is too much crowning, the travel all concentrates in the center, and ruts are occasioned in that way. If these ruts are on a steep grade, the water follows them instead of running to the sides of the road and tears out the material. Another point should be remembered, that a road should be constructed with an inch to a half inch more crown than is permanently designed for it, as the bulk of all travel is in the center, and this would settle the center more quickly than the sides. The writer's experience is that a crown of 12 in. in a 30 ft. road, settling to 10 in. soon after completion, is about the desideratum. An extra allowance of 2 in. should, however, be given to grades steeper than 5 ft. in 100 to shed water more quickly, and on all steep grades breaks or thank-you-marms should be put in about 400 ft. apart to make the shed doubly sure.

On the matter of proper drainage I would lay especial stress. Of course I do not suggest in the construction of these proposed State roads that an elaborate system of underdrainage should be undertaken, but I do insist that under certain circumstances and certain conditions money spent in properly removing accumulating waters is money saved.

In ninety-nine cases out of a hundred it is cheaper to dig or ditch, to drain a hole or pocket or swamp, than it is to fill the place up. Yet to my knowledge money, time and energy have been wasted in filling with stones and bowlders wet and low places in roads, with still unsatisfactory results, when, if one-tenth of the time and energy had been consumed in draining these same places, permanent success might have been insured. In one particular case I remember, on a road that had been traveled for over 100 years, and during that period stones and bowlders had been dumped to keep teams and loads from getting mired, on my proposition of lowering the grade of the road and removing these stones I was solemnly assured of the folly of such a proceeding and undoing a century's work. The result however, proved the contrary, as a good road has existed ever since the new grade was made.

What I would suggest, however, in the general drainage is, that with proper grades care should be taken to shed the water thoroughly at the low points, and if the grades are long, also at proper intermediate points. Where quicksand is struck, or soft, boggy ground, special provision must be made to avoid permanent and unceasing repairs. Quicksand can always be permanently treated by proper drainage, but bogs and swamps of large area cannot usually be so handled. The use of brush and similar material is usually best to make a permanent road under the latter conditions.

Incidental to the crowning and grade, is the proper surfacing of earth for the reception of the road material. Under all circumstances and at all times should the surface of the ground be similar to the finished surface of the roadway, with proper shoulders to hold the material in shape. No dumping the broken stone haphazardly on the existing uneven surface and then spreading it to make the top uniform. This never will, never has made a good roadway, and it is an essential element for successful results in roadmaking to dig out to the depth necessary, to trim off with a proper crown and then put on your stone.

The next problem for consideration is the material to be used for the finished surface, and without taking into consideration the various materials used and suggested for roads, there is only one fit to be used for good, permanent results, and that is trap rock. There is plenty of it in New Jersey, and the only problem is to get it to the place where it is wanted.

This summary conclusion only applies to the finished surface. My own practice is almost uniformly to use a foundation for the support of the broken stones. Occasionally, under pressure of circumstances, I have built thin roads, but not of my own free will, except on steep grades. In fact, of later years I have been varying the thickness of roads according to the grades, making them 10 in. thick for grades flatter than 1 ft. in 100, 8 in. for grades between 1 and 4 in 100, and 6 in. for grades steeper than 4 ft. in 100. This practice I have found gives uniformly good results. I am satisfied, however, that it is feasible in a country with gravelly soil to lay thin pavements and have them last well, but in no other localities except on steep grades do I think it wise to have no foundation.

The material for foundations may be of any durable stone; even water-worn sandstone is not objectionable, but, if round, they should be broken into parts, as such round stone are apt to work to the surface. In my early construction of roads I was very strenuous about having trap rock foundations, and even now mostly use that material for that purpose, as it is as handy as any other in the region in which I am constructing roads, but in sections of the State remote from trap rock quarries I do not think it economy to haul the foundation stone so far.

Under all circumstances the foundation stone should be laid by hand, close together, firmly wedged with smaller stone on top, and this whole mass thoroughly sledged to a uniform surface.

And just at this point I want to lay special stress on the importance of sledging and wedging any foundation that is put in, for in my observation in the ordinary practice of repairing country roads it has been customary to use a great deal of field stone to help out these soft places, and with proper handling of the material used in such places, a fairly successful road might have been made. The result, however, was that, after the layer of earth that had been put on was washed or worn off, the road was very uneven and very much rutted, and somewhat of a torture to travel on. The cause of this was due to the fact that whereas in wedging and sledging the foundation you are enabled to distribute the load of a heavy wagon traveling over it, under the old way the concentrated weight came on individual stones, which sink and yield an insecure or yielding bottom.

The thickness of foundation should not be less than 5 in. and as thick as the run of the material will permit. I built a mile of road with the foundation stone taken out of an old stone fence. It was found cheaper to put them on the road as they were than to break them, and the result was the foundation averaged about 10 in. thick. I must strongly allude, however, to the danger of using perishable stone in the foundation. Better have none at all than material liable to decay.

Having laid and constructed a good foundation for the road, it is then ready for the top course, which should be, except in very special occasions, of trap rock. Before putting in the broken stone, it is better to spread a thin layer of loam or clay, just sufficient to fill the spaces of the stone and make an even surface. Care should be taken not to have too much, as it does no good and harms the road. This packing, as it is called, is put there to prevent the bottom stones from coming up and mixing with the top course, which they are almost sure to do without its interposition. The usual size for the broken stone is from 1½ to 2 in. in diameter, for on this part of the work depends the future smoothness of the road, and only men specially adapted to this kind of work should be allowed to do it. In my experience, few men have or get the proper knack of spreading.

After the stone has been put on to the proper thickness and evenly spread, it should then be rolled, and here comes in again another point of discussion. Years ago it was considered imperative in the construction of a good road to have a steam roller. Experience, however, showed that a road could be constructed as well without it, and the trouble caused by the breaking in of culverts, scaring horses and deterring travel generally within a mile of a steam roller led first to its condemnation by the community, and finally to its abandonment. No steam roller is used to my knowledge on any of the roads in Essex County, and I am glad of it.

A roller weighing about 2 tons, easily moved by two horses, is all that is necessary, costing say $150 to $175, which should be purchased and owned by any community which is building roads.

The rolling of the top stone should be sufficient to bring the stones down to a fairly uniform surface; another thin coating of loam is put on, and this is then repeatedly rolled, and the usual practice is to put on top of this a coat of broken stone screenings, which is then rolled, and then travel is allowed to come on.

I wish to say at this point that while the top coating of screenings is very desirable, where great economy is desirable I think it can be dispensed with, for if it is possible to repair roads by covering them with a coating of 3 in., and then rolling it properly and covering it with loam, I see no reason why new roads cannot be finished off in the same way. It requires a little more care, and you have to have a certain amount of travel to make it a success. I repaired the main avenues of Essex County in that way for years, and their condition was an indorsement of the method.

To do it properly, however, after the top stone is rolled and the coating of loam is also rolled, let the travel come right on. This makes ruts and furrows which a repeated rolling will remove, and let this be kept up till the surface is consolidated. The roller need not be kept in one spot all the time; let it go ahead and roll a new piece, come and smooth off an old piece, and so backward and forward, still, however, progressing regularly forward.

When you have arrived at this period of your road's construction the general idea is that that is all, but I wish to say here very emphatically, not yet. A new road, like a new watch, wants watching and adjusting to get it into a new, permanent shape, and for the first year it wants to be looked after with some care.

After the settling and adjusting have taken place and everything is satisfactory, a road built as here outlined will last from three to five years for ordinary country travel.

I have known a pavement always in good condition to run ten years without repairs, and in my own case parts of the old Pompton turnpike, with fairly heavy country travel, had no repairs on them for five years, and were good at all times.

Now I come to another feature of the road question, which to my mind is more important than all others, and that is their repair.

While the road taxes in this State show that the repair of ordinary earth roads is an accepted fact, and money is voted therefor all over the State, when a pavement is laid down there seems to be a sort of recognized feeling that when it is built that is the end of it. Far from it.

In repairing roads I want to depart from the usually accepted doctrine and say do not patch. The old practice and theory of keeping men on the roads perpetually tinkering and mending is wrong in principle and expensive in practice. If a road is built properly it should wear uniformly, and when its thickness is so reduced that it is necessary to re-cover it with broken stone, let it be done in sections as large as you please, from a mile to one-half a mile, and it should be laid, spread, and rolled in the same manner as described for the building. Of course it may, and undoubtedly will be, necessary to touch up stray places that under peculiar conditions are defective. These should be attended to, but as a general practice I say again, do not patch.

The remarks I made about screenings in construction are still more applicable to repairs. If you can afford it, put them on; they make a nice road, but are expensive, as a coating of loam costs $30 to $50 a mile, and a coating of screenings $300 to $400.

We now come to the important question of cost. Roads built in the manner I have described cost in Essex County 60 to 80 cents per lin., ft. 16 ft. wide, according to their thickness and the distance the material has to be hauled, including foundations of quarry stones. This would be $3,000 to $4,000 per mile. By using local stone for foundation and local help in hauling, and as much as possible local labor, and also reducing width on many of the local roads to 14 ft. and even 12 ft., I think the cost throughout the State might be placed at $2,500 per mile, provided due economy and wise administration is secured.

In the cost of repairs a proper recoating of the surface in the same locality will cost from 20 to 25 cents per lin. ft. for a 16 ft. road. This, by reducing the width and supposing a renewal every five years, would amount to about $150 per mile on the average. On the basis of $2,500 per mile for construction, and $150 per mile per annum for repairs, let us see where the problem would land us.

By the report of the different municipalities and townships submitted to the governor for the year 1888, we find 169 townships reporting an expenditure of $537,000 for the construction and repair of public roads. There are about 247 townships in the State, and basing the calculation on the same rate would give an expenditure of $785,000.

As, however, these returns include the counties of Hudson, Essex, Bergen, Passaic, and Union, which have and are now completing a system of roads of their own at a large expense, it would be proper to deduct these counties from the above statement. Deducting therefrom the reported expenditure of 35 townships in those counties amounting to $238,368, we have the reported expenditures of 134 townships amounting to $299,000 for the rest of the State. As there are about 202 townships outside the five counties mentioned, this would give us an expenditure of $450,000 in one year for the repair and maintenance of their roads, which in ten years would amount to the sum of $4,510,000, enough to pave and macadamize, on the basis of $2,500 per mile, 1,800 miles of roads—and repair 3,000 miles of pavement for ten years. In making a superficial estimate of the miles of roads in the State, I find they run about 50 miles to a township, so with 202 townships there will be about 10,000 miles of road to improve outside the five counties.

The most astonishing part of the matter, to my mind, is that this vast sum of $451,000 per annum is practically thrown away. Roads that have been in existence 50 or even 100 years have had enough money spent on them to make them and keep them as first-class macadamized roads, yet practically they are in the same condition now as years ago, always bad.

THE DISTRIBUTION OF ENERGY BY GAS.

MR. DENNY LANE (of the Cork, Ireland, Gas Company), referring to the advent of his company in the field of electric lighting supply, remarks that there was a time when the proprietors of gas works were so much alarmed by the advent of the electric light that they parted with their shares at a heavy loss. Experience has proved that their fears were ungrounded, and, in fact, the consumption of gas has increased more rapidly in the last decade than it had in any previous period. The very stir that was caused by the threatened competition roused the energies of gas engineers, who were waxing fat, and perhaps growing lazy, after many years of unbroken prosperity. I always alleged that the electric light would never injure the shareholders in gas companies; on the contrary, it has conferred benefits on them, which may, in my opinion, be considerably increased. As I have devoted a good deal of time and thought to the connection between gas and electricity, I will endeavor to point out a mode by which each may be made to help the other. A celebrated old theological treatise is called "*Concordantia Discordantium Canonum.*" In the same spirit, I would wish to evoke harmony out of the discord which is supposed to exist between these two brilliant rivals.

The subject naturally divides itself into three heads—the generation, the storage and the distribution of the agents to be employed.

With respect to generation of illuminating gas, there is not much hope for any substantial improvement. The practice of three quarters of a century has naturally developed highly an industry which yields residuals that return a large proportion of the first cost of the raw material. I believe that the cost of labor in gas making will certainly be reduced to the extent of 2d. or 3d. per 1,000 cubic feet; but beyond this I see no probability of further economy. With reference to heating gas, it is, however, a different question. I believe such gas can be produced at a price lower than that of 16 candle gas, but, of course, it would require separate mains.

With respect to the generation of electricity from motive power, we cannot hope for any improvement. With the many admirable dynamos which are now procurable, it is a proud thing for electricians to say that they have left no room for improvement. When dynamos convert from 90 to 95 per cent. of mechanical into electrical energy, they have far exceeded the results obtained in every other analogous transformation, and by so doing have endowed their favorite science with one of the brightest of the jewels that adorn her crown.

Next, as to storage. The gas engineers have this immense advantage, that their hourly production need not be more than the *average* demand of 24 hours of midwinter, while the electrician who does not use storage cells must have producing power sufficient to meet the heaviest hour, or, in fact, *minute*, in the year, although that may require five or perhaps ten times the average consumption. On the other hand, if he employs accumulators, he has to meet a heavy first cost and a depreciation which, with a fair interest on capital, will run up to 15 or 20 per cent. per annum. Nevertheless, I believe that for those hours (and in summer they are long ones) in which the demand for light is low, great economy will result from the partial employment of these most useful garners of energy.

The third point to be looked into is distribution; and when I first worked out the problem, I own I was surprised at the low cost of the distribution by means of gas supplied to gas engines. My surprise was increased and confirmed lately on reading the excellent lectures which Mr. Kapp has delivered on the transmission of energy. I saw more clearly than before the great losses incurred by the transfer of energy in every other case except that furnished by gas mains. In many cases the existing mains are capable of transmitting as much gas as would in all probability be required for electric lighting at present prices. I think it fairer, however, to calculate what would be the expense of separate mains laid to supply electric substations. I do so for four reasons: (1) Because this gives the total cost of distribution. (2) Because it gives an opportunity of supplying cheap gas of good heating but low illuminating power, which might also be used for stoves and cooking. (3) Because it affords the means of increasing the supply of gas as the demand for electricity increases, without throwing undue pressure on the service pipes of ordinary consumers. (4) Because the unaccounted-for gas would be very small. In fact, gas companies get paid for what is delivered at the consumer's meter—a quantity considerably less than that supplied at the inlet of the distributing mains. But the loss can easily be accounted for by minute leakages in the innumerable joints of the service pipes and connections to the meter—each small in itself, but, when multiplied by myriads, making up an important aggregate. With a good main, carefully laid, and not tapped for services, the leakage would be small, and should not amount to 1 per cent. of the quantity delivered. In such a case the pressure can be increased considerably without causing any notable loss or any inconvenience to ordinary consumers.

Of course, gas will not travel through a main without some propelling force; but the amount required is extremely small, as may be judged from the following example: As water weighs about 62½ lb. per cubic foot, the weight of a column of water of 1 foot area and 4 inches deep is under 21 lb. This gives what is called "4 inches of pressure." In a good gas engine, the consumption of gas should not be more than 24 cubic feet per brake horse power when at full work; but I will allow one-fourth more—thus making a more ample provision for the extra proportion of friction which exists when the engine is not working up to its full capacity. We therefore have for the power employed to force enough of gas through the mains for 1 horse power, $30 \times 21 = 630$ foot-pounds. As a horse power for 1 hour means $(33{,}000 \times 60)$ 1,980,000 foot-pounds, our propelling power is only 1,980,000 ÷ 630, or the $\frac{1}{3143}$ part of a horse power. In other words, 1 horse power employed at the works would force through the mains as much gas as would supply 3,000 horse power at 4 inches difference of pressure.

Of course, the quantity of gas that can be sent though a main depends on the size of the main and on its length, varying in practice directly as the square of the diameter, and inversely as the square root of the length. But I will give a practical example, taking my figures from "Barlow's Tables." I find that a 6 inch main 1 mile long will deliver 9,000 cubic feet of gas per hour at the difference of pressure of 4 inches, which I have given above; and if we divide this by 30 cubic feet, we get 300 horse power delivered at this modest difference of pressure.

Let us see now what the cost of such a main would be. At £5 a ton (in many places the price is less) a 6 inch main costs 4s. a yard, or £352 a mile. If with turned and bored joints, the cost of laying would be 1s. 6d. a yard in a paved road, or £132; making in all £486—let us say £500—a mile. The interest on this at 5 per cent. would be £25, or 1s. 8d. per horse power per annum. If, however, the pressure were increased to 16 inches, double the quantity of gas would be delivered, while the motive power absorbed would be considerably under 1 horse power at the time of the maximum delivery of 600 horse power for 1 mile. I believe no other instance can be given of so moderate a cost for the transference of energy. Counting the cost of gas at 2s. 6d., we have in the first case 300 horse power transferred one mile by the expenditure of $300 \div 3{,}000 = 0{\cdot}1$ horse power or 0·1d. In the second case, we have 600 horse power carried a mile at a cost less than ½d. But besides this remarkable economy, we have also the following advantages. The cartage of coal to, and of ashes from, a station is done away with. No nuisance is caused by the escape of smoke or of steam; and, if the foundations are properly arranged, and the base of the engines isolated from the surface of the ground, no damage will be caused by vibration. The whole space occupied by boilers will be saved, and, where the space is of value, a building of three floors—the two lower containing gas engines and dynamos, and the upper story giving room for attendants and regulating gear—can be employed.

But, again, a most important saving would be made in attendance. Practically, a good gas engine requires no continuous attendance. A daily supply of oil, and an inspection which need occupy only a quarter of an hour, are all that is necessary. I can say this from several years' experience. Formerly there was some difficulty in starting gas engines. Now several contrivances enable this to be effected without any trouble. Again, the wear and tear of gas engines is extremely small. At works here (Cork) a small engine has run for upward of 56,000 hours. At the end of that time it required a new lining to the cylinder, which cost 2½ per cent. of the first cost of the engine. The slide valve required to be scraped occasionally; but the slide valve has been dispensed with in engines of modern make. This engine, although working continuously night and day, is looked to only twice in the 24 hours, in order to give a supply of oil, and take the index of the meter. It is working in a yard where it is exposed to some extent to the dust of coke—one of the most active grinding materials we know; and but for this, it is probable the cylinder lining would have lasted longer. Now, if a station is supplied with a small proportion of storage cells, I think I may assume that the dynamos will not be required for more than 5 hours a day on an average—say, 1,800 hours a year. If my data, therefore, be correct, a gas engine should work for 20 years, and then may require a new cylinder lining, which would come to 2½ per cent. of the first cost. To this must be added the insignificant cost of new piston rings required occasionally.

Compare this with the wear, tear and maintenance of steam engines, remember the wages of stokers and engineers, and I think a remarkable economy in the up-keep and attendance of the gas motor must be admitted. Again, with the best boilers, it takes a considerable time to get up steam; and in work necessarily intermittent, the heat accumulated in the boiler and setting is wasted. We are thus burning the candle at both ends *without deriving any light from it.* It is this cause which runs up the cost of coal for electric light stations so very high. Dr. Fleming estimates it at from 9 to 22 lb. per unit sold. In one case in the North of England, I find that the consumption is 23·4 lb. per unit. On the other hand, a gas engine can be started in less than a quarter of a minute; and as soon as it is stopped, all consumption of fuel ceases. Hence its great economy whenever the demand for power is intermittent. Next as to the chance of breakdown or interruption. The steam engine and boiler form a very complex arrangement. If any serious injury to any of the essential parts takes place, the whole system is made inoperative; and in most cases the boiler must be stopped occasionally for cleaning, examination and repairs. On the contrary, the gas engine is extremely simple in construction.

Of course, "accidents will happen in a family as well regulated" as that of the gas engines; but fortunately these are very rare. I will conclude by giving a singular example. At a large printing establishment in Cork, a gas engine worked very irregularly, and finally struck work. Messengers were sent to complain that "the gas was bad," that "there was no pressure," that "the meter was out of order," that "the service was choked"—in fact, the whole litany of complaints was recited. One of our engineers immediately attended, and found nothing wrong with the supply, or apparently with the engine, which, however, refused "to do a stroke of work." On examination, he found that the supply of air to the engine was derived from a pipe which was carried up outside the building to a height of about 8 feet; the object of this arrangement being to take air at a high level, and so avoid dust, etc., which might be drawn in and injure the cylinder, piston and valves. This air inlet pipe was found to be choked; and what, think you, was the nature of the obstruction? It was composed of *thirteen boys' caps.* In fact, there is a school house close by; and the Cork boy, being of a scientific, ingenious and inquiring disposition, noticed that there was a considerable in-draught at each inspiration of the engine, and having been taught that "Nature abhorred a vacuum," he endeavored to secure a "plenum" by tossing another boy's cap close to the end of the pipe, where it performed the pleasing conjuror's trick of suddenly vanishing. Of course, the other boy returned the compliment; and so it went on, and would have gone on, until the caps of the school were absorbed, were it not that the air fiend got so gorged that he lost all appetite, and "died of shortness of breath."

You will, of course, notice that I have said nothing of the cost of gas used in gas motors. I have only dealt with the distrubution through feeders. The present practice seems to depend on distributing from substations at a low pressure, whether the alternating or the continuous current is employed. Of course, the system I advocate dispenses with banked transformers, and would probably use storage cells for a certain portion of the delivery, although equally well adapted for the alternating current.

THE LAKE HEMET WATER CO.'S DAM.

IT appears from the report of Jas. D. Schuyler, consulting engineer, that the dam is about 20 miles east of San Jacinto and 100 miles from San Diego, in the Hemet Valley, at an elevation of 4,200 ft. above the sea.

The capacity of the reservoir formed by the dam, at 150 ft. level, has been computed as follows:

Height, 150 ft.; flooded acres, 738·13; storage capacity, 8,418,217,700 gallons; capacity in miners' inches for six months, 3,600.

The lowest foundations are 13 ft. below base of dam proper.

The intention of the company is to construct the dam to the height of 150 ft., although I have laid the foundations sufficiently broad to carry the structure 10 ft. higher if desired. The class of masonry of which the dam is being built is certainly the finest I ever saw, and I doubt if it has any superior in America in work of this character. Blocks of granite weighing 5 to 10 tons are set closely together in beds of Portland cement concrete, thoroughly rammed into all joints. When completed it will unquestionably be not only the highest, but the finest dam on the continent. From my observations of the flow of the stream, I have no hesitation in saying that in my opinion the water supply from winter storms is sufficient to fill the reservoir to the height of 160 ft. every year.

In addition to the flood waters of winter, the summer showers of July and August will furnish no inconsiderable volume. My observation of several of these showers, which were of almost daily occurrence for several weeks, was that for an hour or two the stream would flow at the rate of 250,000,000 to 300,000,000 gallons daily, diminishing to the normal low water flow of about 3,000,000 gallons daily, in 15 to 20 hours. I think the reservoir would receive an addition of 50,000,000 to 150,000,000 gallons from each of these showers, and sometimes considerably more. This source of summer supply, which is a resource peculiar to the Southern California mountain region, is likely to afford an effective increase in the duty of the reservoir of 10 to 15 per cent. The constant flow of the stream in summer is more than sufficient to offset the loss by evaporation on the surface of the lake.

As the area of dry lands in the valley requiring water is greater than any possible supply available, it seems to be a profitable and safe proposition to carry the dam to its utmost limit of height. It is possible to go still higher than 160 ft. but not advisable, on account of the necessity of building a considerable length of auxiliary dam in the gap in the ridge south of the main dam, the lowest point in which is 133 ft. above the base.

The masonry has now reached a height of 38 ft. above base, or about 46 ft. above the lowest bottom. The organization is fully effected and working smoothly, the plant is complete and operating successfully as planned, and with reasonably good luck the structure can be completed to the 150 ft. level in a year from this time.

The thickness of the dam at the extreme bottom is about 100 ft., which is greater than its length, or the width between cañon walls at the height of 50 ft., dimensions which have no parallel for stability among dams in the known world.

COMPRESSED AIR AS A STREET RAILWAY MOTOR.

THE MEKARSKI CAR SYSTEM AT TOLEDO.

IN Nantes, France, 25 cars; at Nogent, near Paris, each motor in addition to its own passengers draws two trailers; at Marseilles, cars are operated with a storage pressure of 1,200 pounds, and at Berne, Switzerland, the system is in operation.

The Mekarski system has been incorporated in New York under the name of the Mekarski American Compressed Air Motor Company, is promoted by the Rand Drill Company, of New York City, and under the immediate direction of J. F. Lewis, of that company. The work in Toledo is in charge of a French engineer, a Mr. Gregoire.

The car is similar to those in everyday use, except possibly the body of the car, which is a few inches higher than other four-wheel cars, to permit of the air reservoirs clearing the street safely.

The air compressors are two in number, placed side by side and each driven by a horizontal steam engine, the piston rod of the steam engine extending on and through the cylinders of the air pumps; the engines in the present instance together developing 200 horse power, and are sufficient to keep ten cars supplied by running under 75 pounds steam as many hours as the ten cars are on the line. The compression is practically the same as for other purposes, except perhaps in that the air is heated by steam while passing into the reservoirs, of which there are two. The pumps may charge direct to the car through the reservoirs, or having filled the latter, may remain idle while the motor car is filled. This car is 16 ft. long inside, 22 ft. over all, 6 ft. 6 inches wide, with wheels at standard gauge, and 8 ft. wheel base.

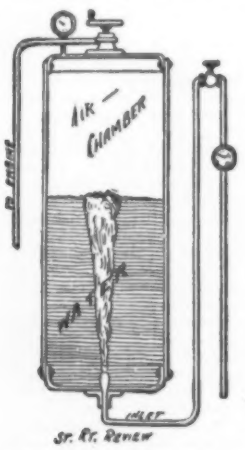
Entrance is made at rear, the front platform being inclosed with a dash of usual height with swinging gates, and for the exclusive use of the driver. The car must either take a loop or turn table at end of the line, or, as was the case in Toledo, make the return trip running backward. Beneath the car, incased in sheet iron, with side doors, are the air tanks, engines and air brakes, none of which are visible. The reservoirs are cylinders, eight in number, are in two series, one of three, the other five, all connected at will of the driver. They are placed horizontally across the car, are made of ⅜ in. thick steel, and each contain 90 cubic ft. of air. They are tested to 1,000 but are only charged to 600 pounds.

The two engines, each of 5 in. cylinder, with 8 in. stroke and of 15 horse power, drive directly to the wheels of one axle, or may be connected to drive all four wheels like a locomotive. The under frame of the car is of steel. The air brakes, placed between the wheels, are very quick and effective, and operated by two vertical cylinders, which raise the point of a V-shaped hinge joint, and lock the wheels instantly. On the front platform stands a tank of copper quite like a soda fountain cylinder. It stands about 36 inches above the floor, and carries two gauges and the controlling valve. At the right is the ordinary lever for working the link motion—for setting a forward motion, reversing or cutting a short stroke. One gauge shows the number of pounds reserve in the reservoirs, the other the pressure in the platform tank, which is

the pressure on the engines; for the supply is regulated at will and must pass through this equalizing tank on its way from storage tanks to engines. And here is the vital principle of the Mekarski system. This equalizing tank is partly filled with hot water, which is charged at the power station while the storage tanks are receiving air, and it is this passing of the air through the hot water which heats it sufficiently to overcome the low temperature which otherwise would occur in the engines. The hot water remains sufficiently warm for an hour or more.

The trial trip was made from the power house along the principal business street of Toledo, and on tracks used jointly by the horse and electric cars of both the Toledo Electric and the Consolidated Companies. Where traffic was heavy and at cross streets the car either crept along or darted ahead to take advantage of any available stretch of open track. Upon reaching the residence street a turn or two of the valve was quickly answered by an immediate increase in speed, which was raised from four to sixteen or eighteen miles an hour in going a distance of about three car lengths. This speed was fully and uniformly maintained for three quarters of a mile, when the motor overtook a horse car and was held back.

The start from a dead stop was made easily, without any jerk or jar whatever, and a high speed quickly attained. The working of the air engines was quite a surprise, in that they practically make no noise, and the exhaust is so muffled that it is not noticeable unless one is specially watching to detect it; and even then, after the car is in motion, the ordinary rumble of the car drowns it. The pressure indicated by the gauge on the equalizing tank—the one containing the hot water—varied according to the necessities of the case. A full stop was made in the middle of a sharp curve and where the guard rails were badly filled with frozen mud, and at the start the pressure was raised to 280



EQUALIZING TANK FOR HEATING AIR.

pounds, but was allowed to drop in a few seconds to 150 pounds. On straight level track the car starts easily at 150 pounds.

After starting, an 8-mile speed was maintained with 50, and eighteen miles with 100 pounds. Frequent sudden stops and starts were made, such as are rarely ever required in actual service, to illustrate the ability of the machinery to do its work, one stop being so sudden as to have instantly thrown down standing passengers. While moving at nearly a four mile speed, one stop was made in four feet and a few inches, the air brakes in every instance doing their work easily, quickly and very effectively. The intensity of the application of the brakes lies entirely with the driver, and should there ever be a failure of the brake, or any necessity for extra action, the reversing of the engines is the work of but an instant.

The return trip was necessarily made with the car running backward, owing to the lack of loop or table at terminus, but was in every way a success. On the return trip stops were made for passengers and a good load picked up.

On entering the power house after making the round trip of four and a half miles, the reserve tanks still showed a pressure of 320 pounds, while the work performed by reason of the numerous starts and stops was considerably in excess of what would ordinarily occur in daily service. The motor exhibited the same strength on entering the power station as was shown when it first went out.

The car rides smoothly, and offers no objectionable features to the public or horses on the street.

The car rides very prettily, the public seem to like it, horses pay no more attention to it than any other horseless cars, and we failed to detect any objectionable feature in its operation, either to sight, smell or hearing. It would seem then to be largely a question of cost per car mile, a question of which the manager must be his own best judge. The first cost for power plant and equipment of motor cars would not in our judgment militate against the system. The fact that the Consolidated Company at Toledo are preparing to install a complete plant, after having one car in daily operation for several weeks, would indicate their confidence in the system. The recharging process occupies from five to six minutes. We could detect no loss of pressure from leakage while car was standing at terminus some fifteen minutes, and are informed there is no loss from this source, so that a car might remain out a week and get home again without recharging, though the cooling of the water tank would doubtless involve some difficulty. The water retains its heat easily for 60 minutes or more, according to the outdoor temperature, yet at no time was the tank so hot as to prevent one keeping his hand thereon.

The manufacturers tersely say of the motor:

"The car will run between eight and nine miles without recharging, and is handled with ease and promptness, all the motions being under perfect control, and requiring but a very slight expenditure of physical force on the part of the driver. Its speed varies at the will of the driver from 3 to 25 miles per hour. It can be brought to a dead stop in less than its own length. It stops and starts with the same facility on heavy grades or curves, and in every instance, moves promptly, with no jerky motion whatever."

Where lines are more than four miles long, or where the round trip includes over eight miles, an additional power station would be necessary. Power station, however, is quite simple, requiring only boilers, steam and compression engines and storage tanks. The illustration will give a good idea of this. As many cars can be charged at one time as desired, by having a sufficient number of feed pipes from reservoir.

Mr. Gregoire recommends additional power stations as against one large central station piped to the several points of supply.

Altogether the operation of the car was full of interest and mechanically was a success; just what the expense or economy of the system is we are not yet informed.

In our judgment the operation of the car requires no greater skill or knowledge of mechanics than is required to drive a cable or electric car. Several of the company's employes in the car house have learned in a few trips so as to be fully competent to take the car out, and in fact do so daily, as the car is in service most of the day.—*Street Railway Review.*

HIGH PRESSURE FIRE EXTINGUISHING APPARATUS.

THE necessity of providing means for dealing effectively and promptly with fires in the initial stage led to the adoption of Vinning's apparatus at the South Kensington Museum in November, 1889; the same apparatus was also successfully applied in several other cases. The apparatus, however, could then hardly be said to have been out of the experimental stage, and important improvements in this appliance have since been introduced by the High Pressure Fire Main Company, London.

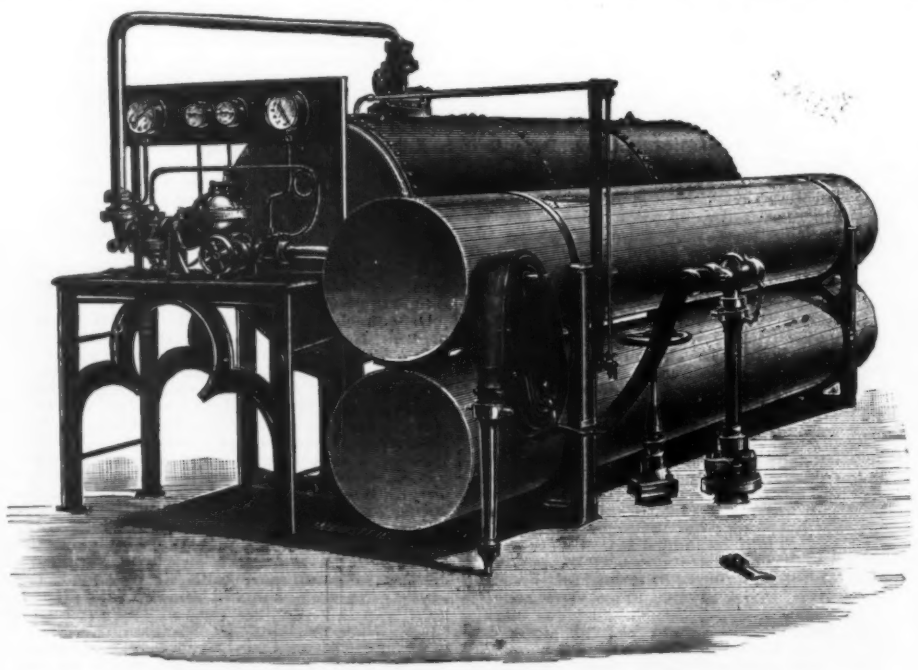
The system consists essentially of the storage of air at very high pressure, which can be at a moment's notice brought to act upon a supply of water in a closed vessel, the pressure varying with the requirements of the situation. The air is kept stored in cylinders proportional to the amount of water it is desired to utilize, and here the improvements lately effected at the suggestion and after the designs of the company's engineer, Mr. J. W. Turner, are evident. Instead of the apparatus being a scattered series of cylinders and water tanks, the whole is grouped neatly and effectively in a compact system, shown in the engraving given below.

From the air cylinders a pipe communicates with a stop valve, by which the pressure is retained until the apparatus is required to be set in operation. From this stop valve the air passes to regulating and reducing and safety valves, and so to the top of the water tank, which is provided with a float ball valve. The function of the latter is to allow the air to pass upward when the tank is being filled with water, but closes automatically when full. At the base of the water tank is another float ball valve, which falls as soon as all the water is discharged, and prevents the air from entering the fire mains. By turning a wheel the main stop valve is opened, and the compressed air is brought to act, at a reduced pressure, upon the water to be delivered at any of the fire cocks in the building to be protected. The advantage of dealing with fire *at once* and before the possible arrival of the steam fire engine is apparent. Briefly, the apparatus possesses for a time—which is dependent on the size of the plant—all the advantages of a powerful steam fire engine always on the spot and ready for action.

Owing to the improvements lately effected, the company's engineer has been able to apply the system to manual fire engines. This feature overcomes the objections hitherto associated with the hand or portable appliances generally used, in which the pressure decreased from the moment of turning on the water. By the high pressure apparatus the same pressure is maintained in the water reservoir until all the water is discharged, leaving a large surplusage of air pressure for a fresh supply of water.

Another appliance, patented by the company, enables whole districts to be covered by the apparatus. The chief features claimed for the High Pressure Fire Main Company's appliances are as follows:

They are unaffected by fluctuations of pressure; they are always ready; they provide instantaneously



GENERAL VIEW OF HIGH PRESSURE FIRE EXTINGUISHING APPARATUS.

the advantage of a powerful steam fire engine; and are absolutely certain in their action.

We have recently had an opportunity of witnessing trials of the apparatus shown in the engraving, which has a capacity of 500 gallons, and is fitted up at the works of Messrs. Horton & Son, boilermakers, Park Street, Southwark. The air at a pressure of 250 lb. was stored up in the reservoirs shown, and admitted at the reduced pressure of 94 lb. into the water tank, 3 ft. in diameter. Water was ejected through nozzles—varying in size from ¼ in. up to 1 in.—from 180 ft. up

to 150 ft., by simply turning one valve. The apparatus is simple of operation, the reducing, cushioning, and safety valves, shown in the engraving, being previously set, and not requiring any further attention in case of an outbreak of fire.—*Industries.*

THE DYNAMOS AT FRANKFORT EXHIBITION.

By W. B. ESSON.

THE Maschinenfabrik, Esslingen, exhibited an eight pole 60 kilowatt dynamo. This machine is coupled direct to a horizontal compound engine, and gives, at a speed of 100 revolutions per minute, a current of 124 amperes, at a difference of potential of 480 volts. The armature is 114 cm. in diameter, and has a drum winding, there being 694 conductors on its exterior, counted all round the periphery. The armature core is built up of iron plates, 1 mm. thick, separated from each other by paper, and the whole is supported by a strong cast iron center piece, keyed to the engine crank shaft. The commutator has 347 segments, insulated with mica, and the ring carrying it is secured to the armature casting above mentioned. In connection with the commutator, it should be mentioned that this machine is quite exceptional in having mica between the segments, the insulation used almost universally for German machines being of "presspahn," or cardboard made from wood pulp. The radial magnets are cast in one with the octagonal frame which supports them, the latter being jointed vertically, as shown. Two sets of brushes, at 45° angular distance apart, collect the current which flows through the 694 conductors in two parallels. The engine cylinders are 32·5 cm. and 50 cm. diameter, respectively, and the stroke is 60 cm. The working pressure is 8 atmospheres, and the steam is admitted by double beat valves in conjunction with trip gear, the point of cut-off being controlled by the governor. The combination exhibited gives for each kilogramme of steam a return of 71 watt hours with, and 52 watt hours without, a condenser, the exhibitors stating that their object has been not to get a dynamo which does a large quantity of work for its weight, but one from which is obtained the highest electrical return for the consumption of a given quantity of fuel.

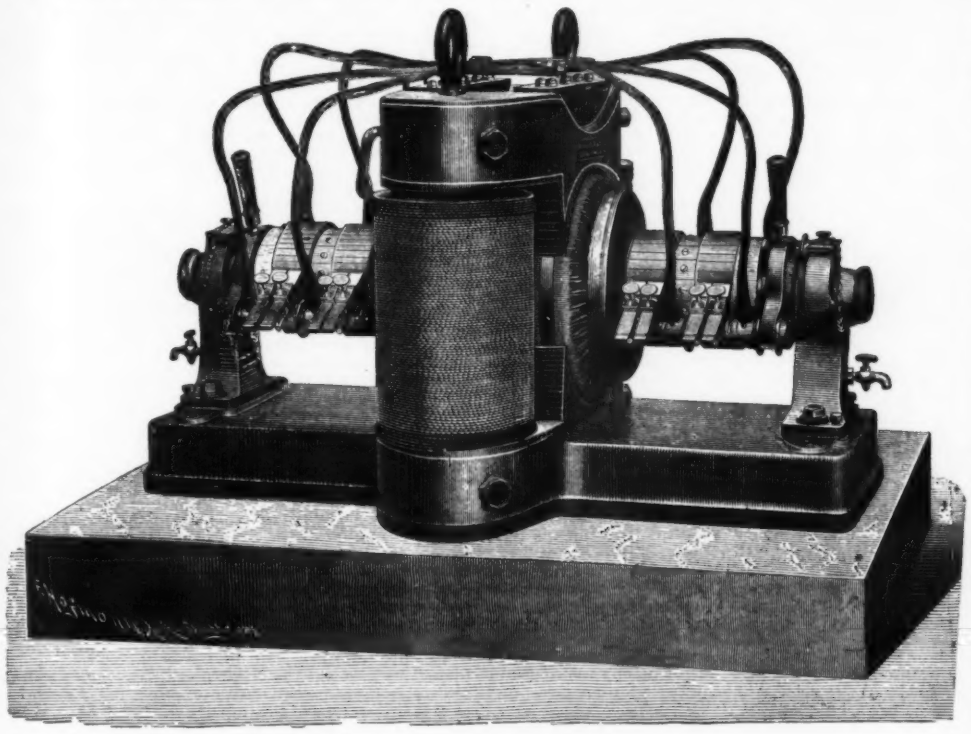


FIG. 1.—THE COMPENSATOR.

The machine above described is shunt wound, and supplies current through a five-way system of distribution. The two outside conductors of the system are connected to the machine terminals, while the three intermediate conductors are connected up to a compensating motor dynamo. This compensator consists of the machine illustrated in Fig. 1, which has an armature Gramme wound, with four distinct circuits connected up to four separate commutators. The magnet winding is a shunt to the two outside wires, and the excitation is consequently constant, due to a potential of 480 volts. It will be seen from the diagram of connections, Fig. 2, that all the commutators are joined in series, the first and fifth conductors being connected outside the two extreme ones, and the second, third, and fourth between consecutive ones. When all the four circuits take through R_1, R_2, R_3, and R_4, the same current, the motor dynamo is driven by a small current flowing through the four armature windings, A, B, C, and D, in the same direction. If in one of the branches, say R_2, the resistance is increased, the difference of potential between the two conductors, 2 and 3, rises by a very small amount, while in the other branches it falls. The consequence is, that, while the armature increases in speed a little, the winding, B, between the wires 2 and 3, receiving current and acting as a motor, the other three windings, A, C, and D, are acting as generators, the current now flowing in an opposite direction through them and an E.M.F. being added to the circuits, R_1, R_3, and R_4,

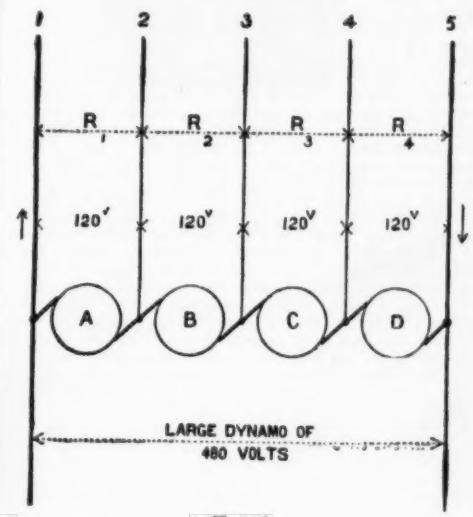
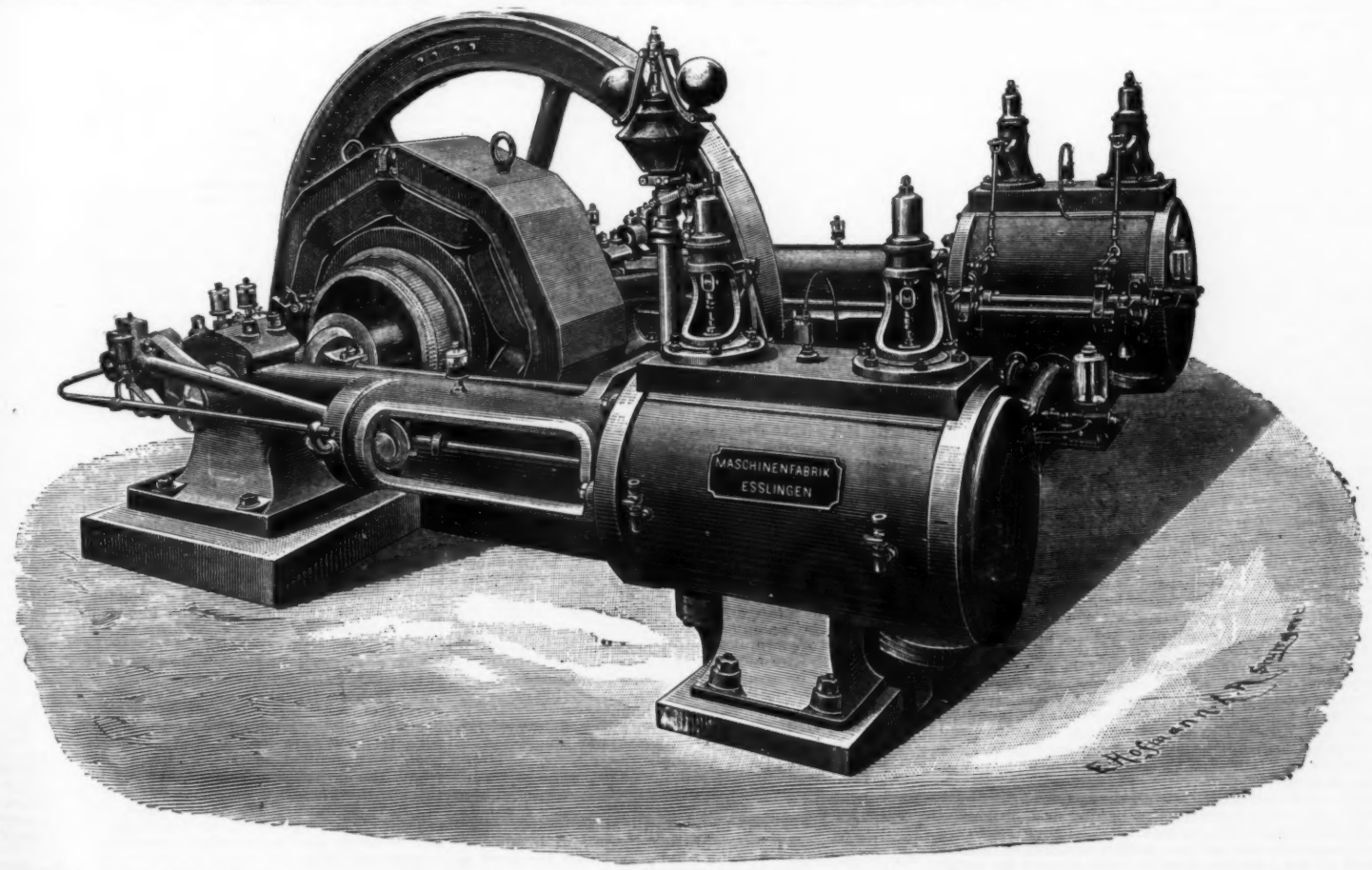


FIG. 2.

with which they are connected. The compensator in this way keeps the difference of potential for each circuit constant, always running as a motor and taking power from the least loaded circuits, to give it back, acting as a generator, and raising the potential of the circuits loaded more heavily. The writer is assured that the compensator acted most efficiently, the four voltmeters in the branches showing no perceptible deviation from 120 volts.

Current may be taken direct from the terminals of the machine at 480 volts, or, if desired, from the middle wire and one outside one at 240 volts. At the former pressure it was supplied to the 50 horse power four-pole motor used to pump the water from the Main quay to the lake in the exhibition grounds, and for this purpose the dynamo had to run nearly all day, as the water was used for condensation in several steam engines. The other electromotors coupled to the system were supplied with current at 120 volts, as were also all the arc and glow lamp circuits.—*Electrical Review.*



THE MASCHINENFABRIK 8 POLE 60 KILOWATT DYNAMO AT FRANKFORT EXHIBITION.

SOME POSSIBILITIES OF ELECTRICITY.

By WILLIAM CROOKES.

WE know little as yet concerning the mighty agency we call electricity. "Substantialists" tell us it is a kind of matter. Others view it, not as matter, but as of a form of energy. Others, again, reject both these views. Professor Lodge considers it "a form, or rather a mode, of manifestation of the ether." Professor Nikola Tesla demurs to the view of Professor Lodge, but thinks that "nothing would seem to stand in the way of calling electricity ether associated with matter, or bound ether." High authorities cannot yet even agree whether we have one electricity or two opposite electricities. The only way to tackle the difficulty is to persevere in experiment and observation. If we never learn what electricity is, if, like life or like matter, it should always remain an unknown quantity, we shall assuredly discover more about its attributes and functions.

The light which the study of electricity throws upon a variety of chemical phenomena—witnessed alike in our little laboratories and in the vast laboratories of the earth and sun—cannot be overlooked. Without going into transcendental speculations as to the origin of all things, it may be mentioned that the theory which now meets with most favor as best representing the genesis of the chemical elements is, that at the time each element was differentiated from the all-pervading *protyl*, it took to itself definite quantities of electricity, and upon these quantities the atomicity of the element depends. Professor Oliver Lodge expresses this when he says, "Every monad atom has associated with it a certain definite quantity of electricity; every dyad has twice this quantity associated with it; every triad three times as much, and so on."* Helmholtz considers it to be probable that electricity is as atomic as matter, and that an electrical atom is as definite a quantity as a chemical atom. This, however, must not yet be regarded as a certainty, for it is possible that all the facts at present known may be explicable in another way. If an atom of matter is endowed with the property of taking to itself one, two, three, or more units of electricity, it does not follow that electricity is atomic. Imagine the atoms of matter to act like so many bottles, capable of holding one, two, three, or more pints. Imagine electricity to be like water in the ocean, which for the purposes of this argument may be considered inexhaustible and structureless. One of the atomic "bottle" elements dipped into the ocean would certainly take to itself one, two, three, or more pints of water, but it would by no means follow that the ocean was atomic in that it was capable of being divided up into an infinite number of little parcels, each holding a pint or its multiple.

For this and other reasons I think we must accept the hypothesis of the atomic character of electricity as not yet definitely proved, although it is not improbable.

I have spoken of the "ether"—an impalpable, invisible entity, by which all space is supposed to be filled. By means of the ether theory we can explain electrical phenomena, as well as those appertaining to the phenomena of light.

Until quite recently we have been acquainted with only a very narrow range of ethereal vibrations, from the extreme red of the solar spectrum on the one side to the ultra violet on the other—say, from three ten-millionths of a millimeter to eight ten-millionths of a millimeter. Within this comparatively limited range of ethereal vibrations and the equally narrow range of sound vibrations, all our knowledge has been hitherto confined.

Whether vibrations of ether, longer than those which affect us as light, may not be constantly at work around us, we have, until lately, never seriously inquired. But the researches of Lodge in England and of Hertz in Germany give us an almost infinite range of ethereal vibrations or electrical rays, from wave lengths of thousands of miles down to a few feet. Here is unfolded to us a new and astonishing world—one which it is hard to conceive should contain no possibilities of transmitting and receiving intelligence.

Rays of light will not pierce through a wall, nor, as we know only too well, through a London fog. But the electrical vibrations of a yard or more in wave-length of which I have spoken will easily pierce such mediums, which to them will be transparent. Here, then, is revealed the bewildering possibility of telegraphy without wires, posts, cables, or any of our present costly appliances. Granted a few reasonable postulates, the whole thing comes well within the realms of possible fulfillment. At the present time experimentalists are able to generate electrical waves of any desired wave length from a few feet upward, and to keep up a succession of such waves radiating into space in all directions. It is possible, too, with some of these rays, if not with all, to refract them through suitably shaped bodies acting as lenses, and so direct a sheaf of rays in any given direction; enormous lens-shaped masses of pitch and similar bodies have been used for this purpose. Also an experimentalist at a distance can receive some, if not all, of these rays on a properly constituted instrument, and by concerted signals messages in the Morse code can thus pass from one operator to another. What, therefore, remains to be discovered is—first, simpler and more certain means of generating electrical rays of any desired wave length, from the shortest say of a few feet in length, which will easily pass through buildings and fogs, to those long waves whose lengths are measured by tens, hundreds, and thousands of miles; secondly, more delicate receivers which will respond to wave lengths between certain defined limits and be silent to all others; thirdly, means for darting the sheaf of rays in any desired direction, whether by lenses or reflectors, by the help of which the sensitiveness of the receiver (apparently the most difficult of the problems to be solved) would not need to be so delicate as when the rays to be picked up are simply radiating into space in all directions, and fading away according to the law of inverse squares.

Any two friends living within the radius of sensibility of their receiving instruments, having first decided on their special wave length and attuned their respective instruments to mutual receptivity, could thus communicate as long and as often as they pleased by timing the impulses to produce long and short intervals on the ordinary Morse code. At first sight an objection to this plan would be its want of secrecy. Assuming that the correspondents were a mile apart, the transmitter would send out the waves in all directions, filling a sphere a mile in radius, and it would therefore be possible for any one living within a mile of the sender to receive the communication. This could be got over in two ways. If the exact position of both sending and receiving instruments were accurately known, the rays could be concentrated with more or less exactness on the receiver. If, however, the sender and receiver were moving about, so that the lens device could not be adopted, the correspondents must attune their instruments to a definite wave length, say, for example, fifty yards. I assume here that the progress of discovery would give instruments capable of adjustment by turning a screw or altering the length of a wire, so as to become receptive of wave lengths of any preconcerted length. Thus, when adjusted to fifty yards, the transmitter might emit, and the receiver respond to, rays varying between forty-five and fifty-five yards, and be silent to all others. Considering that there would be the whole range of waves to choose from, varying from a few feet to several thousand miles, there would be sufficient secrecy; for curiosity the most inveterate would surely recoil from the task of passing in review all the millions of possible wave lengths on the remote chance of ultimately hitting on the particular wave length employed by his friends whose correspondence he wished to tap. By "coding" the message, even this remote chance of surreptitious straying could be obviated.

This is no mere dream of a visionary philosopher. All the requisites needed to bring it within the grasp of daily life are well within the possibilities of discovery, and are so reasonable and so clearly in the path of researches which are now being actively prosecuted in every capital of Europe, that we may any day expect to hear that they have emerged from the realms of speculation into those of sober fact. Even now, indeed, telegraphing without wires is possible within a restricted radius of a few hundred yards, and some years ago I assisted at experiments where messages were transmitted from one part of a house to another without an intervening wire by almost the identical means here described.

The discovery of a receiver sensitive to one set of wave lengths and silent to others is even now partially accomplished. The human eye is an instance supplied by nature of one which responds to the narrow range of electro-magnetic impulses between the three ten-millionths of a millimeter and the eight ten-millionths of a millimeter. It is not improbable that other sentient beings have organs of sense which do not respond to some or any of the rays to which our eyes are sensitive, but are able to appreciate other vibrations to which we are blind. Such beings would practically be living in a different world from our own. Imagine, for instance, what idea we should form of surrounding objects were we endowed with eyes not sensitive to the ordinary rays of light, but sensitive to the vibrations concerned in electric and magnetic phenomena. Glass and crystal would be among the most opaque of bodies. Metals would be more or less transparent, and a telegraph wire through the air would look like a long narrow hole drilled through an impervious solid body. A dynamo in active work would resemble a conflagration, while a permanent magnet would realize the dream of mediæval mystics and become an everlasting lamp with no expenditure of energy or consumption of fuel.

In some parts of the human brain may lurk an organ capable of transmitting and receiving other electrical rays of wave lengths hitherto undetected by instrumental means. These may be instrumental in transmitting thought from one brain to another. In such a way the recognized cases of thought transference, and the many instances of "coincidence," would be explicable. I will not speculate on the result were we eventually to catch and harness these "brain waves."

Whatever be the length of the electric wave, the velocity with which it travels is constant, and is equal to the velocity of light, or about one hundred and eighty thousand miles a second. Professor Oliver Lodge, who has worked for some years on these subjects, gives* formulæ for calculating the frequency of vibration and the wave length of the electrical rays given by the discharge of Leyden jars of different capacities. The bigger the jar and the greater the size of the circuit the longer will be the waves. Thus a pint jar discharging through a two yard circuit will give waves of a length of fifteen or twenty meters, and they will follow each other at the rate of ten millions a second. A jar the size of a thimble will give waves only about two or three feet long, and they will succeed one another at the rate of two hundred and fifty or three hundred millions a second. With every diminution in size of the apparatus the wave lengths get shorter, and could we construct Leyden jars of molecular dimensions, Professor Lodge considers the rays might fall within the narrow limits of visibility. We do not know the intimate structure of a molecule sufficiently to understand how it could act as a Leyden jar, yet it is not improbable that the discontinuous phosphorescent light emitted from certain of the rare earths, when excited by a high tension current of electricity in a good vacuum, is really an artificial production of these electric waves, sufficiently short to affect our organs of vision. If such a light could be produced more easily and more regularly, it would be far more economical than light from a flame or from the arc or incandescent lamp, as very little of the energy is expended in the form of heat rays. Of such production of light Nature supplies us with examples in the glow-worm and the fire-flies, whose light, though sufficiently energetic to be seen at a considerable distance, is accompanied by no liberation of heat capable of detection by our most delicate instruments.

By means of currents alternating with very high frequency, Professor Nikola Tesla has succeeded in passing by induction, through the glass of a lamp, energy sufficient to keep a filament in a state of incandescence without the use of connecting wires. These lamps possess one interesting feature; they can be rendered at will more or less brilliant by simply altering the relative position of the outside and inside condenser coatings. If exhausted glass tubes are used as the source of light, very beautiful effects are produced. The electric generator is capable of exciting the tubes at a considerable distance, and the luminous effects are very striking. For instance, if a tube be taken in one hand, the observer being near the generator, it will be brilliantly lighted, and will remain so, no matter in what position it is held relatively to the observer's body. Even with tubes having no electrodes there is no difficulty in producing by this means sufficient light to read by, and the light will be considerably increased by the use of phosphorescent materials, such as yttria, uranium glass, etc.

The ideal way of lighting a room would be by creating in it a powerful, rapidly alternating electrostatic field, in which a vacuum tube could be moved and put anywhere, and lighted without being metallically connected with anything. Professor Tesla has obtained such a condition by suspending, some distance apart, two sheets of metal, each connected with one of the terminals of the induction coil. If an exhausted tube is carried anywhere between these plates it remains always luminous. In such a room, in addition to the luminous phenomena mentioned, it is observed that any insulated conductor gives sparks when the hand or any other object is approached to it, and the sparks may often be powerful.

Alternating currents have at best a somewhat doubtful reputation; but it follows from Tesla's researches that, as the rapidity of the alternation increases, they become incomparably less dangerous. It further appears that a true flame can now be produced without chemical aid—a flame which yields light and heat without the consumption of material and without any chemical process. To this end we require improved methods for producing excessively frequent alternations and enormous potentials. The energy required is very small, and if light can be obtained as efficiently as theoretically it appears possible, the apparatus need have but a very small output. For the production of light at least, the heavy machinery at present in use would seem to be unnecessary. There being a strong probability that the illuminating methods of the future will involve the use of very high potentials, one of the problems in the near future will be to perfect a contrivance capable of converting the energy of heat into energy of the required form. The extent to which this new method of illumination may be practically available experiment alone can decide. In any case our insight into the possibilities of static electricity have been extended, and the ordinary electrostatic machine will cease to be regarded as a mere toy.

Another tempting field of research, scarcely yet attacked by pioneers, awaits exploration. I allude to the mutual action of electricity and life. No sound man of science indorses the assertion that "electricity is life;" nor can we ever venture to speak of life as one of the varieties or manifestations of energy. Nevertheless, electricity has an important influence upon vital phenomena, and is in turn set in action by the living being, animal or vegetable. We have electric fishes—one of them the prototype of the torpedo of modern warfare. There is the electric slug, which is reported to have been met with in gardens and roads about Hornsey Rise, and which, if touched, occasioned a momentary numbness of the finger tip. There is also an electrical centipede. In the study of such facts and such relations the scientific electrician has before him an almost infinite field of inquiry.

If we take a bird's eye view of the solid work that lies ahead, the first requisite is certainly a source of electricity cheaper and more universally applicable than the tedious conversion of chemical energy into heat, of heat again into mechanical power, and of such power into electric current. It is depressing to reflect that this roundabout process, with losses at every step, is still our best means of obtaining a supply of electricity. Until this is accomplished, we are still haunted by the steam engine with its clouds of smoke and its heaps of cinders and ashes. Water power to set dynamos in action is only available in exceptional cases, and very rarely indeed in our country. While we are seeking for cheaper sources of electricity, no endeavor must be spared to tame the fierceness of those powerful alternating currents now so largely used. Too many clever electricians have shared the fate of Tullus Hostilius, who, according to the Roman myth, incurred the wrath of Jove for practising magical arts, and was struck dead with a thunderbolt. In modern language, he was simply working with a high tension current, and, inadvertently touching a live wire, got a fatal shock.

We know that the rays of the arc light, allowed to act judiciously on plants, may, to a more or less extent, compensate for lack of solar heat and light; but so long as electric energy is so costly, we cannot bring this interesting fact into industrial practice. In respect to vegetation, it is still uncertain whether electrical currents exercise any decided or uniform influence upon growing crops of grain or fruit; or whether such influence would be favorable or the reverse. Experiments tried by the late Sir W. Siemens lead to the opinion that electricity may induce earlier and better harvests; but much further study is here needed. Nor have we yet solved the equally important and closely connected question, whether we may by electrical action rout the parasitical insects and fungi which in some seasons rob us of no less than the tenth of our crops. A moderate estimate puts the mean loss in the home kingdoms at £12,000,000 per annum. In India and some of the colonies, a number of destroyers, which it is not my business to specify, are less easily contented. Like Falstaff, in the words of Dame Quickly, they seek to take, "not some, but all." The attacks of the phylloxera have cost our French neighbors more than did the Franco-Prussian war.

It has been found in not a few experiments that electric currents not only give increased vigor to the life of the higher plants, but tend to paralyze the baneful activity of parasites, animal and vegetable. Here, then, is unlimited scope for practical research, in which the electrical engineer must join forces with the farmer, the gardener, and the vegetable physiologist. We have definitely to decide whether, and under what circumstances, electricity is beneficial to our crops; and whether, and under what conditions, it is deadly to parasitic pests.

With regard to the possible applications of electricity to agriculture, I may mention that the total amount

* "On Electrolysis," British Association Reports, 1885.

* *Modern Views of Electricity*, pp. 246-7.

of its vis viva which the sun pours out yearly upon every acre of the earth's surface, chiefly in the form of heat, is 800,000 horse power.* Of this mighty supply of energy, a flourishing crop utilizes only 3,200 horse power, so that the energy wasted per acre of land is 796,800 horse power. We talk loudly of the importance of utilizing the refuse of our manufactures; but what is the value of alkali waste, of furnace slags, of coal tar, or of all of them together, compared to the loss of 796,800 horse power per acre?

The application of electricity to sanitary improvements is another possibility, turning again mainly on a cheap supply of current. The electrical treatment and purification of sewage and industrial waste waters is a demonstrated reality which merely requires a reduction in the cost of the agent employed.

The sterilization, *i. e.*, the destruction of disease germs by electrical means, of the water supply of cities has been proposed and discussed. Theoretically, it is possible, but the practical difficulty of dealing with the vast volumes of water required for the daily consumption of London is prodigious. But, "a difficulty," said Lord Lyndhurst, "is a thing to be overcome." There is a still more important consideration; the living organisms in water are by no means all pathogenic—many are demonstratively harmless, and others are probably beneficial. Pasteur proposed to bring up young animals on sterilized food and drink with a view to determine whether their health and development would be affected for the better or for the worse. Decisive results are not yet forthcoming. Before the sterilization of our water sources can be prudently undertaken, this great question must be first decided by experimental biologists.

Another point at which the practical electrician should aim is nothing less than the control of the weather. We are told that these islands have no climate—merely samples—that an English summer consists of three fine days and a thunderstorm, and that the only fruit that ripens with us is a baked apple. There is more than a grain of truth in this sarcasm. The great evil of a thunderstorm in this country is not that the lightning may kill a man or a cow, or set barns or stacks on fire. The real calamity consists in the weather being upset. The storm is followed by a fall of temperature; and a fit of rain, clouds and wind, which rarely lasts less than a week, sadly interferes with the growth and ripening of grain and fruits. The question is, Cannot the accumulations of electric energy in the atmosphere be thwarted, dispersed, or turned to practical use? In like manner we may hope to abate the terrible fog nuisance, which is now in point of time no longer confined to the month of November, and by no means limits its attacks to London. It has been shown that during a genuine London fog the air is decidedly electro-positive. What the effect would be of neutralizing it would not be very difficult to show.

We hear of attempts at rain-making, said to have been more or less successful. Shall we ever be able, not to reduce our rainfall in quantity, but to concentrate it on a smaller number of days, so as to be freed from a perennial drizzle?

I shall, perhaps, be styled a dreamer, or something worse, if I remotely hint at still further amending the ways of nature. We all know, too well, that cloudiness and rainfall occur chiefly by day, and clear skies at night. This is precisely the opposite distribution to that which our crops require. We need clear heavens by day, that the supply of sunshine may not be interfered with, and we want clouds at night to prevent the earth losing by radiation the heat which it has gained in the day. As we have just seen, nature supplies energy amply sufficient. How is this enormous quantity of power to be made available? These are problems which may safely be left to the devices and the inspirations of our electrical engineers.

I have thus glanced at some of the intricate electrical problems to be solved—some of the enormous difficulties to be surmounted. Progress, a word now in the mouth of every one, may—as Dean Swift observed—be too fast for endurance. Sufficient for this generation are the wonders thereof!—*Fortnightly Review.*

HOW TO MAKE A STORAGE BATTERY.

By GEORGE M. HOPKINS.

PROBABLY no secondary battery can be more readily made or more easily managed than the one invented by Plante. It is, therefore, especially adapted to the wants of the amateur who makes his own apparatus. It takes a longer time to form a Plante battery than is required for the formation of some of the batteries having plates to which the active material has been applied in the form of a paste, and its capacity is not quite equal to that of more recent batteries, but it has the advantage of not being so liable to injury in unskilled hands and of allowing a more rapid discharge without injury.

Each cell of the battery consists of 16 lead plates, each 6 × 7 in. and $\frac{1}{16}$ in. thick, placed in a glass jar 6 × 9 in., with a depth of 7½ in. Each plate is provided with an arm 1½ in. wide and of sufficient length to form the electrical connections. The plates are cut from sheet lead in the manner indicated at 3 in Fig. 1, *i. e.*, two plates are cut from a sheet of lead 8½ × 14 in. This method of cutting effects a saving of material. The plates, after being cut and flattened, are roughened. One way of doing this is shown in Fig. 2. The plate is laid on a heavy soft wood plank and a piece of a double cut file of medium fineness is driven into the surface of the lead by means of a mallet. To avoid breaking the file, its temper is drawn to a purple. After the plate is roughened on one side it is reversed and treated in the same way upon the opposite side. If a knurl is available, the roughening may be accomplished in less time, and with less effort, by rolling the knurl over the plate. Half of the plates are provided with four oblong perforations, into which are inserted H-shaped distance pieces of soft rubber, which project about $\frac{1}{8}$ in. on each side of the plate. The perforated and imperforate plates are arranged in alternation, with all of the arms of the perforated plates extending upward at one end of the element and all of the arms of the imperforate plates similarly arranged at the opposite end of the element. The plates are clamped together by means of wooden strips—previously boiled in a paraffine—and rubber bands. The strips are placed on opposite sides of the series of plates at the top and bottom, and the rubber bands extend lengthwise of the strips.

FIG. 2.—ROUGHENING THE PLATE.

FIG. 3.—PLATES CONNECTED.

The arms of each series of plates are bent so as to bring them together about three or four inches above the upper edges of the plates. They are perforated to receive brass bolts, each of which is provided with two nuts, one for bending the arms, the other for clamping the conductor.

The element thus formed is placed in a glass cell, and the formation is proceeded with as follows: To hasten the process, the cell is filled with dilute nitric acid (nitric acid and water equal parts by measure), which is allowed to remain for twenty-four hours. This preliminary treatment modifies the surface of the lead, rendering it somewhat porous, and, in connection with the roughening, reduces the time of formation from four or five weeks down to one week. The nitric acid is removed, the plates and cell are thoroughly washed, and the cell is filled with a solution formed of sulphuric acid 1 part, water 9 parts.

The desired number of cells having been thus prepared, are connected in series, and the poles of each cell are marked so that they may be always connected up in the same way. The charging current, from whatever source, should deliver a current of ten amperes with an electro-motive force ten per cent. above that of the accumulator. Each cell of this battery has an electro-motive force of two volts, and the voltage of the series of cells would be the number of cells × 2. It is a simple manner to determine the amount of current required to charge a given series of cells. For example, a battery is required for supplying a series of incandescent lamps. It has been found uneconomical to use lamps of a lower voltage than sixty. It will, therefore, require a battery having an E. M. F. of sixty volts to operate even a single lamp. This being the case, at least thirty cells of battery must be provided, and, on account of a slight lowering of the E. M. F. in use, two extra cells should be added. It will, therefore, require thirty-two cells for a small installation, and the machine for charging such a battery should be able to furnish a current of ten amperes, with an E. M. F. of seventy-five volts.

FIG. 4.—COMPLETE CELL.

To form the battery, it is placed in the circuit of the dynamo and kept there for thirty hours continuously, or for shorter periods aggregating thirty hours. It is then discharged through a resistance of twenty or thirty ohms, and again recharged, the connections with the dynamos being reversed, so as to send the current through the battery in the opposite direction. The battery is again discharged through the resistance, and again recharged in a reverse direction. These operations are repeated four or five times, when the formation is complete. It will require from five to seven hours to charge the battery after it is thoroughly formed. It must always be connected with the dynamo as connected last in charging.

Although amateurs may find pleasure in constructing and forming a secondary battery, there is no economy in securing a battery in this way. It is less expensive and less vexatious to purchase from reliable makers.

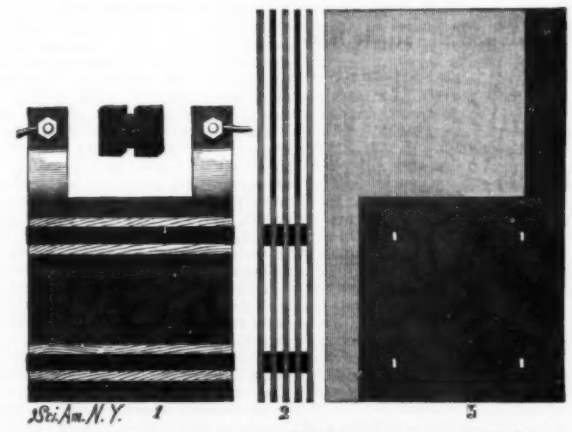


FIG. 1.—PLATES OF SECONDARY BATTERY.

ACTION OF ELECTRIC CURRENTS UPON THE GROWTH OF SEEDS AND PLANTS.

By Dr. JAMES LEICESTER.

A.—ZINC plate buried in the soil and about 1 sq. ft. in size.

B.—Plate of copper having the same dimensions as the zinc plate, and connected at the top by a copper wire above the surface, C, with the copper plate, B.

D.—A box about 3 ft. long and about 2½ ft. wide filled with soil.

By means of the apparatus shown in Fig. I. a weak current can be passed through the soil. The strength of the current will vary with the amount of organic acids in the soil. A series of experiments were conducted with the object of finding out whether these weak currents would in any way affect the growth of seeds and plants. In order that there could be good comparative tests, a number of glass vessels were obtained, all of the same size, filled with similar soil, and exposed to the same conditions, such as temperatures and sunlight. In some of these were placed earth plates, as shown in A (Fig. II.), whereas the others only contained the soil.

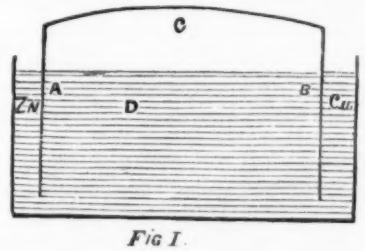


FIG I.

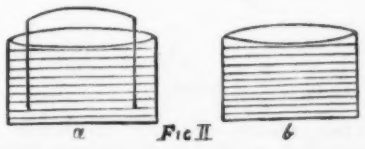


FIG II.

They were watered each day at the same time and with equal quantities of water. Various seeds were obtained, and the same number of seeds sown in both vessels at the same time and under the same conditions. In all cases the seeds grew very much quicker in the vessels containing the earth plates. In the case of hemp seed it was fully an inch above the surface before there was any sign of it in the ordinary vessels.

Larger plates have been made connected as before and buried in the ground a few feet apart. In these larger experiments the same results were obtained. Seeds were sown in drills as shown in Fig. III. Those in the zones, *a*, *b*, *b'*, were the first to appear. Next came those in the zones *c* and *c'*. Those sown at *d* and *d'* came up nearly a week later than the others.

In order to vary this experiment the earth plates were next buried where *d* was, and fresh seeds sown. The greatest fertility was then noticed to be in the

* "The Perplexed Farmer," by George Ville. English edition, by W. Crookes.

neighborhood of *d*, that is to say, between the two plates.

With regard to plant life, experiments are now being conducted, but so far no distinct difference has been noticed in the case of those under ordinary conditions and those with the earth plates. If the soil is watered with a little very dilute acetic acid, the growth of the seeds is much quicker in the case of the earth plates,

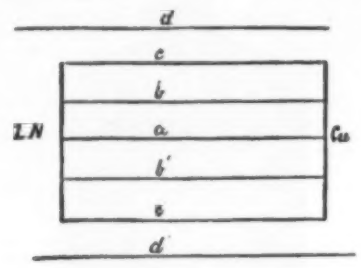


FIG III

but no difference is noticed in the ordinary vessels. The latter result is probably due to the slight increase in the strength of the current due to the action of the acetic acid.

These earth plates are hardly practicable on a large scale, but might be used in frames or for forcing under glass.—*Chem. News.*

THE ACTION OF HEAT FROM OPEN FIRE GRATES, STOVES, AND HOT WATER PIPES.

By F. DYE.

THOSE who make a profession of hot water works, or heating by hot air or by stoves, almost invariably make it a point to deprecate the use of open grates, and to show that with these articles very irregular results are the general rule, and for a given amount of heat they are not very economical in fuel. On the other hand, the maker of the open fire grate can claim advantages for his manufactures which the other methods of heating do not possess, and he can just as readily deprecate these other methods in question, owing to their having disadvantages which are absent when the open grate is used.

Speaking as favorably of the open grate as possible, it has to be admitted that, with the average of those that are now in use, the heat evolved is very irregular indeed, and even with careful stoking the effect, by way of heat distributed into the room, for a given quantity of fuel, is less than with either of the other methods referred to. Let it be clearly understood, however, that this last paragraph is intended to apply to the average grate now in use, as quite the majority consist of what are commonly termed "registers," having a register flap at back, and no provision to reduce the speed of combustion. This is an old pattern grate, and is very greatly improved upon by many new grates, more lately introduced, and which will be alluded to directly as they more nearly approach perfection. These latter, however, are not yet in the majority by any means.

From this it will be gathered that the heat evolved from open grates is different in action and results to that obtained from stoves and water pipes, and requires to be treated distinctly in these papers. In the same way the two methods usually form two distinct trades or callings, and the one deprecates the other as a rule, as just mentioned.

The mode by which heat is transmitted from the fire of an open grate to the persons or objects in a room is termed "radiation." Now, radiant heat acts in a manner peculiar to itself, first in sending its rays in direct lines from the source of the heat, and anything that does not come within the area or focus that the rays cover will not get heated by them, and would remain quite cold were it not that other indirect agencies cause the radiated heat to ultimately raise their temperature. The rays or lines of heat from the glowing fuel travel, as just stated, in direct lines from this source; but they diverge, or spread out, somewhat as they get away. The exact sum of their divergence is stated as follows: "The amount of radiant heat received by a given surface varies in the same proportion or ratio as the inverse of the square of the distance from the source of heat."

Fig. 1 illustrates and makes this technical rendering

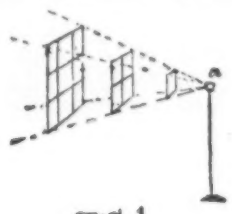


FIG. 1

clear (*a* being the source of heat). It will be seen by this figure that as the rays of heat get further and further from their source they become more distributed as to the area they act upon, and a moment's thought will show that as they thus widen out they lose in power or intensity, and this is why it is that as we get further and further away from a fire the heat gets less and less. It is nothing else, for even if the fire were outdoors and the air in motion, it must not be thought that air or wind would make any difference to the direct course of radiant rays of heat. As an instance, to show that these rays travel in such distinctly direct lines, let any one place a screen between them and the fire, and see how instantly the heat is cut off. The same with a sunshade and the sun's rays. The heat does not curl round the edge of these screens and strike the person who is shielded behind them, for it will be found that the shadow cast by a sunshade is wanting in heat, the same as it is wanting in light.

Now when radiant rays of heat (more frequently called radiant energy, for heat has been found to be nothing more or less than motion) strike or impinge upon an object, the temperature of this object is raised; it is made warmer, more or less, as it is capable of quickly or slowly absorbing heat. When it has received heat it at once commences to reradiate, to redistribute it by radiation. This second radiation of heat is not so strong as the first from the fire, but is none the less certain, and it travels in the same direct lines. The lines of heat may, however, in this case proceed to some part of a room where the primary rays do not reach, and here they go to warm other objects, which in their turn distribute the heat again in different directions, and so it goes on. We might say the heat is tossed from one article to another about the room and so distributed; but this process goes on rather slowly, and when a fire is first lighted in a room, it is some time after the direct radiant heat is felt before the parts that do not receive these first, and more powerful, rays are warm. This reradiation of heat is one of the causes of the distant and remote parts of a room becoming ultimately warm.

If the direct rays of heat from a fire encounter a polished surface, there is instantly an active dispersal or deflection of the warmth. The action is essentially the same as with a ray of light that encounters a polished object. By an arrangement of mirrors, or such surfaces, it would be possible to divert the heat as desired, but this arrangement is neither practical nor probable.

Another and most active source of heat diffusion is the action of "convection." The word diffusion is correct here, as the way in which convected heat acts has no straight lines, or such rules governing it, but causes the heat to transfer itself here, there, and everywhere in a rapid, and effective, and independent manner.

"Convection" is derived from the word *conveho*, to carry up, and is the act of conveying heat by the ascent of heated particles of air or liquids. It is this action that we depend upon in a hot water apparatus, and without it we could have no circulation of water. It acts in the same manner with air, only more rapidly. The action of convection is as follows: The air, or atmosphere, is composed (like water) of an innumerable quantity of minute particles or molecules, these minute particles all being quite distinct and independent of one another, and, furthermore, being wholly devoid of friction or resistance of this kind in their movements. In all solid substances we look for friction to manifest itself more or less according to the surface of the particles of the substance; for instance, if we piled up jagged pieces of stone, we could make the heap a considerable height, owing to the friction brought to bear by the rough shape of the pieces preventing their slipping. If we attempted to make a heap with, say billiard balls, we should not get along so well; but, to give an idea what absence of friction there is among the particles of liquids and gases, let any one try and make a heap of water.

Most authorities agree that there is not only absence of friction among fluids (liquids and gases) but also a positive repelling influence, for it is found in exhausting the receiver of an air pump that although the air gets more and more diminished as the pumping is continued, yet, when the quantity is very reduced, it still pervades the whole of the space, though in an attenuated form. What remains in the receiver does not collect in one spot; but the particles spread themselves about, getting as far apart from one another as possible, it would seem, and this phenomenon is just as noticeable when the air left in the glass is only about $\frac{1}{1000}$ its original contents.

Having shown that air is composed of exceedingly small particles, ready to move freely in any direction that they may be impelled, the actual process of convection can be explained as follows: When air comes in contact with a heated object, those particles which have contact become heated also (for air absorbs heat readily), but directly the particles increase in temperature they also increase in size; they expand with heat, like every other substance, solid or fluid, does. Now, when a substance or particle is increased in bulk without increase in weight, it is rendered lighter than its smaller fellows. If we had a piece of cork 2 in. square, and a piece of wood 1 in. square, both weighing exactly the same, we should call the cork the lighter material, owing to its having greater bulk for a given weight. The particles of air, therefore, that are warmed and rendered lighter than their fellows are instantly displaced and caused to rise by the superior weight of the latter, and as the new cold particles come in contact with the heated object, so they are warmed and lightened, and caused to rise also.

Fig. 2 illustrates a heated ball, and the arrows indi-

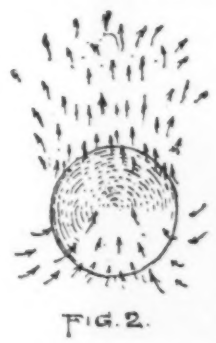


FIG. 2.

cate the action of the air as the particles touch and are carried up in the way explained. The action is so rapid that there will be a constant stream of cool air to the ball, and an equally constant stream of hot air rising from it so long as it remains heated. If any heated object is taken, and some cigar smoke gently blown upon it, it will be seen how quickly the smoke takes an accelerated upward direction when it comes over the source of heat; the heated up current of air carries it with it. This is rather a long explanation devoted to convection, but it is a subject little known, or, at any rate, less known than its kindred subject—radiation. In stove and hot water works the subject of convection is all important, as will be seen directly.

It will now be understood that air coming in contact with furniture and objects in the room which have received warmth by radiated heat instantly sets up convection currents, and this transfers heat to the distant or obscure parts of the room just as readily as the reradiation explained, if not more so in some cases. These convection currents also bring fresh air for respiration, and nature has provided many things which induce these currents of air to our benefit. There is a circulating motion of air induced by everything that has warmth—even the human body itself. If a cold object were introduced into a hot room, this also would induce the action explained, but the movement would be reversed. The warm air particles would be contracted by contact, and they would fall—just the opposite to the explanation given, but just as certain and rapid.

THE ACTION OF HEAT FROM OPEN FIRE GRATES.

An open fire heats the objects near it by radiant rays of heat, and this heat is reradiated about, and also transferred to the air by contact with the warmed objects. The reradiation and the convective action of the air ultimately distributes the heat about the room where the first direct rays do not reach. It will be seen from this that the greatest source of heat is the primary radiant rays from the glowing fuel, next the

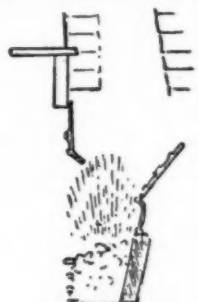


FIG.3

secondary rays (reradiated from warmed objects), and next and least, warmth imparted to the air by contact with warmed objects. Now, this order of precedence is the great feature of the open grate, it heating a room chiefly by radiant heat, and least by warming the air.

All authorities agree that the plan of heating most conducive to health is to provide a fully sufficient heat to the body, but at the same time to have a cold or cool air to breathe. This can be proved in many ways; for instance, by the ease or actual pleasure with which we can breathe the wintry air, provided the body is warmly clothed (and in health). It might have been more plainly stated earlier that radiant heat possesses the peculiar property of passing through air without increasing its temperature, and only heats objects that it strikes or comes in contact with. It is sometimes a little difficult to grasp this, but the common instance adopted by writers to prove its accuracy is to refer to the atmosphere at some distance from the earth; the atmosphere in high regions is always exceedingly cold (as snow-capped mountains prove), yet these high regions are nearer the sun, the source of heat, than the general surface of the earth is. The sun's rays have no warming effect upon the air however hot they may strike persons or objects upon the ordinary surface of the earth.

Now, in addition to the fact that the open grate contributes heat to a room by the most natural way possible, it has two other good features: first, the cheerful appearance of its fire cannot be overvalued. This one feature is a sufficient cause for its still being in favor, without the other advantage just given. In fact, among the general users of the open grate its hygienic value is unknown, and the pleasure the sight of the fire incites gives it preference over other methods of heating. Secondly, there is no more effective (non-mechanical) ventilator than the open fire grate. The chimney, with its wide opening into the room, is a most effective foul air extractor, and cause of fresh air inlet. This can be instantly proved by holding the hand to the crevice of a door or any point where air can find an entrance, and a keen inrush of air will be instantly detected. This inflow of air is wholly due to the updraught in the chimney. Let the fire go out, and then close the chimney opening (the register flap), and the draught through the crevices will disappear.

There is no denying that the average grate is not capable of giving the effective results that other methods of heating can, and neither do we under any circumstances get such a regular or controllable temperature, but, notwithstanding this, the open grate exists, and its existence bears no signs of being terminated, for the improvements introduced of late years have as nearly as possible quite obliterated some of its ill features.

The first attempts in this direction were made with a view of checking the speed at which the fire burnt, and the outcome of this is the many forms of open fire "slow combustion" grates now to be obtained. This is a most desirable improvement, for with the old pattern grates the fire burnt unnecessarily fast when it had once become bright, and the great heat evolved went partly up the chimney and partly to make the heat of the room too great. This was the usual result. With the modern grates the speed of combustion is greatly reduced, and when the fire is bright it remains so for a longer period, giving out a regular heat and other satisfactory results, with a lessened quantity of coal.

This is excellent as far as it goes, but some of these grates have the disadvantage of being slow burning at all times, and a slow rate of combustion is a positive source of annoyance when the fire is first lighted, or at any of the times that it may be required to burn quickly. The fire should, to secure the most agreeable re-

sults, be convertible from slow to fast burning, or the reverse, as required. Most grate makers now provide for this in some way or other, more or less effective.

The next chief improvement effected with the open grate to render it more capable was to prevent such a lavish proportion of the heat passing up the chimney. With the old and common forms of grates there appears to have been an effort made in design to permit of the freest possible escape of smoke and products of combustion into the chimney without regard to the free escape that was thus afforded for heat and such valuable effects. The form known as the "register" grate, with semicircular flap at back just over the fire, is in section like Fig. 3. Another pattern, usually with hobs, is as Fig. 4 (also in section). In these it will be

FIG. 4

seen that the castings forming the backs are intentionally made at an angle to give the easiest passage for the products from the fire to the chimney, and the small lines show what a great proportion of the radiant heat is projected into space where it has no useful effect. In quite the majority of open grates the backs, whether iron or firebrick, are made to slope away back from the fire, and this has been found to be totally opposed to good results so far as heat distribution into the room is concerned.

All modern pattern grates are now furnished with the firebox wholly composed of firebrick (excepting the grating bottom and front bars), and in practically every case the back brick is made to overhang the fire in some way or other. It may be that it gradually slopes forward, or it may project over abruptly at some point. Figs. 5, 6, 7, 8 show some of the forms given these

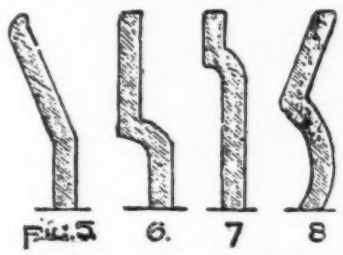


FIG. 5 6. 7 8

bricks, but hardly two makers have their bricks alike, and each, of course, claims some effective superiority over the other. If we take a brick, as Fig. 5, for example (it is an effective brick, and one that an explanation can be given to simply), the more satisfactory heat in the room is brought about as follows: It must first be explained that radiant heat can be deflected, *i. e.*, turned from the direction it was pursuing, by encountering an object placed at a not too abrupt angle, even if this surface that it encounters be the reverse of polished. It acts in the same way as a beam of light would if it was directed against a mirror placed at an obtuse angle. The light would be caused to take a different direction or line to that which it pursued previous to its reaching the glass. The result of the overhanging brick is, therefore, first, the prevention of heat rays passing into the chimney; secondly, the projection of these particular rays into the room, as Fig. 9.

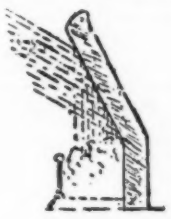


FIG. 9

The next, and as great a gain effected by the brick overhanging the fire, is the utilization of flame heat, a valuable source of heat wholly and utterly wasted otherwise. Flame, for all practical purposes, may be said to heat by contact only. Every one knows what a little heat is radiated or dispersed from a flame. The hand may be placed quite close to it without great inconvenience, but let the hand be just put into the flame (the flame have contact with the hand), its effectiveness is then manifested most obviously. If flame has contact with anything, it will contribute heat to it unsparingly (as in a reverberatory furnace), but without contact it will do but very little work.

We have an excellent example of this with the modern forms of gas fires, the source of heat with these being flame pure and simple, and the flame by itself would be very ineffective, but it is made to impinge upon and to heat a fire brick and some hollow balls of an asbestos composition, and by making these of a bright red heat the stove is rendered a success. If we suddenly turn off the gas when one of these stoves is at a bright red heat, we shall find that for a moment there is about as much heat radiated from the red hot materials as when the gas was alight, showing that the gas flame itself contributed but little to the radiant rays of heat which are the cause of the room being heated.

From this it will be seen what a valuable use can be made of the flame from a coal fire by causing it to impinge upon the back brick, this being effected by the brick overhanging the fire. We do not get the brick at a bright red heat, as in a gas stove, but it gets most intensely hot when the fire has been alight a little time, and then it sends its rays of heat into the room most freely and successfully, for the rays are projected in a downward direction toward the floor, as Fig. 10.

FIG. 10.

It is peculiar to note what a number of advantages are gained by having the back brick leaning over the fire. This projection of heat rays toward the floor is a really valuable one. If we succeed in furnishing sufficient heat to the floor of a room, the air which becomes heated by contact, and rises by its convective action, quickly makes the upper part of the room warm. Grates are now made with the fires as near the hearth as possible, chiefly with this object in view. It is easy to imagine what a difference there would be in heating a place with hot water pipes if we put the pipes up near the ceiling instead of at or beneath the floor. It is doubtful if the place would ever get warm under these circumstances if any effective means of ventilation existed.

The overhanging brick thus sends out heat in two directions at once, that by deflection as Fig. 9 and that by radiation as Fig. 10, both these effects being of a pronounced successful character, and both being results not attainable with the ordinary or old pattern grate already referred to. It may be added that the overhanging brick assists materially in reducing the volume of smoke that would otherwise pass directly into the chimney, and smoke is nothing more or less than unconsumed fuel.

Notwithstanding the excellent results attained with the modern forms of open grates, with the advantages described in the last paper, they still fall short of the efficiency of stoves and hot water pipes. It is upon the points of economy and regularity of heat that the grate is behind the other methods of heating; but, as already described, the latter do not possess some good features that the grate has, and for general domestic purposes it is well known that the grate has still the greatest share, if not all, the favor.

From stoves we have the heat transmitted to us in two direct ways; by radiation from the heated surface of the metal, and by convection of the air that comes in contact with the heated surfaces. This differs from open grates, as with these we have no convective action, except from objects warmed by the radiant heat, and this is trifling compared with that which takes place direct from the highly heated plates of a stove. It is supposed that the stove is of a pattern that has the fire inclosed within it, and not made visible anywhere. If the fire is visible, then we get results intermediate between an open grate and a stove; that is to say, the action of each is manifested. There are many stoves made in this way, with visible or open fires, but they cannot very well be made to keep aight for hours without attention, like a close stove can, and unless this can be done we get the irregular heat of the open grate.

What is now being said, of course, refers to stoves that are fixed in the room or apartment to be heated. If the stove is placed in a chamber constructed for the purpose, and the heat conveyed by pipes or conduits to the place to be heated, the action and results are very different. This latter method is termed "heating by hot air," and will be alluded to directly.

It may be supposed that with a close stove placed in a room the two actions by which the heat is transmitted contribute about a half each to the results attained, that is, the radiant heat does about as much toward heating the room as the heat received by convection (warmed air) and *vice versa*. Now, by referring to the previous papers it will be seen that the air being warmed to this extent is rather opposed to natural results, and to those sufficiently sensitive this way of heating might prove disagreeable. There is, however, another, and greater objection to warming the air, in the fact that it is rendered unnaturally dry. This is a particular drawback, and any one troubled with bronchial affections becomes very conscious of it, and in fact, it is unbearable. Every one knows that the chief objectionable feature of the dreaded east wind is its unhealthy dryness.

It has to be explained that air has, or should have, a certain percentage of moisture in it varying with its temperature, air at a low or cold temperature having, and only being able to hold, a small quantity of water compared to what air can when it is hot. It is peculiar to note that the body is agreeable to this varying degree of moisture, for when the air is cold with its least quantity of water in suspension there is no disagreeable result to speak of; if, however, this air became heated, but without increase of moisture, it would be highly unpleasant and unhealthy. The great difference in this capacity for water that our atmosphere has can be judged by the fact that air at 30° Fah. has, when saturated, only 2½ grains of water in suspension per cubic foot, whereas at 80° it has 10½ grains. The capacity of air for water is about doubled with each increase of 28° to 30° in temperature.

When speaking of the saturation of air, it is meant that the air contains as much water as it can possibly hold. The most agreeable air to breathe is not fully saturated, at least such would be the opinion of most people accustomed to our English climate. A particular purpose that requires a fully saturated atmosphere is a hot house, and, in fact, all horticultural glass house works. In fern houses, for instance, the atmosphere is kept in a state that might almost be described as wet. These places are heated by hot water pipes, which go a great way to render the air dry by warming the air by convection, and it is a primary thought of the gardeners to see that efficient and amply sufficient means be provided to give the necessary moisture to the air. This is effected with vaporizing troughs which are placed upon the hot water pipes. The heat causes the water in them to give off a vapor, and, furthermore, the air will help itself to water where it has opportunity.

With stoves the difficulty is met by the use of water pans, and many stoves are provided with these by the makers; some even having them cast, in an ornamental way, upon the stove itself. The only objection to this arrangement is the possibility of rendering the air too moist, which, although not objectionable in sick rooms with certain maladies, is not a desirable thing when the occupants of an apartment have to go directly in and out of the open air. As a rule, provision for adding moisture to the air is necessary, and without this the air may not only be disagreeable to breathe, but it will, if very dry, help itself to moisture wherever it can, much to the detriment of cabinet ware and such like.

Doubtless many readers have heard the expression that when a stove becomes overheated it "burns the air." This is often mentioned and used as an argument against stoves generally. The expression is wrong, however, utterly so, for the air by contact with hot stoves does not become burnt (? consumed intended); and even if it did, it would not be accountable for the odor of burning that is generally noticeable at such times. The only effect upon the air when the stove is overheated is to render it still more unhealthily dry than ever, and if the stove is any way near red heat, then the air will have an odor like scorching materials do to the innumerable particles of matter that are suspended in the air coming in contact with the hot metal. The dust (the purest of air always has some in it) which floats about, particularly in dwelling houses, is composed almost wholly of organic matters, particles of woolen, cotton and linen material, and a hundred other things that are light enough to be carried up when reduced to such a fine state. This is the cause of the "burnt" sensation that is perceived at such times.

The heating of living apartments by close stoves can hardly be called a success yet; there is opportunity for it to be made so, but it has a very strong opponent in the open fire with its cheerful appearance. If the cheerful effect were by some means abolished from the open fire, its other advantages would hardly be sufficient to keep the stove from conquering it eventually. In many other countries, however, the stove is preeminent; on the Continent the large erection of firebrick in the apartment, and in America the basement stove, with its hot air conduits throughout the house. The latter country, however, is, in its cities, fast adopting the open grate, notwithstanding its rather primitive character.

The particular advantage of the stove (also hot water and hot air works) is the regularity of its heat. With a good stove properly constructed one charge of fuel will last many hours without attention, which must give more regular results than the frequent stoking and burning up and going down of the open fire. In addition to this, every heating apparatus which heats the air contributes heat to the body equally on all sides. This is an argument urged against the open fire, of course, which, by radiation, only heats the side of the body which is turned toward it.

One of the most useful and ingenious inventions in connection with the heating surfaces of stoves is the addition of gills or plates, a series of which are placed along the body of the stove externally, and projecting some 6 in. to 10 in., according to the size of the stove. There are stoves made like this and called "gill stoves," although almost all makers use these gills more or less in some way with stoves that do not bear this name. A gill stove is like Fig. 11. A side section would be as

FIG. 11.

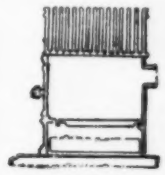


FIG. 12.

Fig. 12, which shows clearly the gills or plates (or ribs, or wings, as they are sometimes called) standing out from the body of the stove which constitutes the fire box. The object of the gills is to prevent the stove overheating, and so having an ill effect upon the air, and also from being a source of danger should any one come against it.

The action of the gills is as follows: When the outer surface, the shell of the fire box, receives heat, this heat is as instantly transferred to the gill plates, the heat traveling into them by the rapid conductive power of the metal of which the stove is composed. Now, if we have a certain quantity of heat (we may call it a quantity for the purpose of this explanation) in a piece of metal which raises it to a certain temperature, it follows as a matter of course that if we increase the size of the metal so as to allow the heat to distribute itself more, the temperature will be reduced, notwithstanding all the heat is still there. We may compare it to a perfume which as it spreads about becomes less strong to the senses, although it is not lost. It is thus with a gill stove; there is a greater quantity of metal to receive the heat, and although the surfaces are not so intensely hot, the greater area of these surfaces compensates, and so we get a large volume of heat at a low temperature, instead of a less quantity at a higher temperature. The result is far more agreeable, the metal does not get so hot as to create odors of any kind, neither should it get hot enough to cause an accident if any one came in contact with it, as might happen with a plain surface. This kind of stove is well suited for hot air works.

For hot air works the stove (or it may be hot water pipes) is placed in a brick-built chamber but little

larger than itself. Into this chamber is a fresh or cold air inlet, and from it are one or more warm air conduits, according to the magnitude of the undertaking, these being brick channels (like chimneys) or earthenware or iron pipes. These conduits terminate in the apartments to be warmed. It will be seen that the heat is contributed in this system by convection only, and, although so extensively adopted abroad, it is not approved of here and but little adopted. Warmth that is due to warmed air is equable, as the stove can be so easily arranged to burn and give out heat regularly; it is also fairly economical, as practically the whole of the heat is utilized, and it possesses the advantage of delivering heat to several different rooms or at several points in one room from a single fire. The gain effected, however, is not appreciated in England, and the more advanced we become the less likely is this mode of heating to become popular. It is possible to obtain good results with practical attention, but in dwelling houses it will not get this. To the best of the writer's belief, the House of Commons is at present heated by hot air, but there are capable men there to attend to the apparatus. There is the most efficient provision for moistening the air that is heated, with hygrometers to indicate its moistness, and other ways by which the air is purified, sweetened, and rendered as agreeable and healthful as it is possible to get it. Notwithstanding this, however, if the heat could be imparted to the occupants of the house without heating the air, the results would be obviously better.

Hood, in one of his editions of "Warming Buildings," alludes to an instance where one of the large clerks' rooms in the Custom House, London, when heated by hot air, resulted in the major portion of the occupants becoming ill and suffering from symptoms which upon inquiry and examination were found to be due to the stoves being overheated, sometimes red hot. The air after passing over them was occasionally 110°, rendered intensely dry, and the smell produced by the decomposition of the matters composing the dust which settled upon the stoves was very disagreeable. This apparatus had such a pernicious effect that it had to be removed. It appears, however, that there had been no provision made for adding moisture to the atmosphere, and with such a temperature and dryness the air would rob even the skin and lungs of moisture.

From hot water pipes we have the same action as from stoves, viz., radiation from their outer surface, and air warmed by contact with them; both these actions, however, are weaker, and this renders them more agreeable. Of course, a greater surface is required with hot water pipes than with stoves to heat a room of a given size. With hot water pipes we get a very agreeable heat, in fact, we get the result that is partially obtained with the "gill" stove explained in the last paper. We get a large volume of heat at a medium temperature, instead of a smaller volume at a higher temperature.

With hot water pipes there is no occasion whatever to provide means for moistening the air, the heat is evolved too gently and naturally for that, and it is the general opinion that with this kind of heating appliance we receive more heat by radiation than by convection. There are exceptional instances where vaporizing pans and troughs have to be provided, even in living apartments, and as before mentioned, such provision has always to be made in horticultural works; but for general residence work, or for warehouses, lecture rooms, etc., no such provision, as a rule, is called for.

In saying that we receive heat from hot water pipes by both radiation and convection, it is supposed that the pipes are exposed, and not in pits, chambers or even in channels; neither should they be incased in any way as the old form of pipe coil usually is. So much of the effective heat is lost or rendered ineffective by hiding the pipes in any of these ways, that the practice should be avoided wherever possible. The new pattern "radiators," which are practically ornamental forms of coils, have been introduced chiefly with the idea of obviating what has just been referred to, as their appearance is such that they may be stood in full view almost anywhere, if they are suitably colored and decorated.

Almost any mode of hiding hot water pipes must have a prejudicial effect upon results in two distinct ways. The first is that we may lose all or nearly all the radiant heat, the value of which has been already dwelt upon. Take the pipes in a church, which are usually carried in channels with an iron grating over. Even with these we get but little radiant heat through the grating, and what does come through is projected into space and does little or no good. The heating in such a case as this is done, we may say, wholly by convection, and so it is with the other methods adopted to hide the pipes. Of course in numbers of works the pipes must be hidden. There may be no way of obviating it. In such cases, as every engineer knows, a greater allowance of pipe is made to heat a certain area than if the pipes were exposed. This is how the difficulty is overcome, but, of course, it does not seem right that any waste of heat and extra expense should occur.

The other and possibly greater objection to placing pipes in channels, pits, or such obscure places is the certainty of their being allowed to get dirty, that is, have a coating of dust, more or less thick, upon them. Now, dust has an objectionable feature when it settles upon stoves, and such highly heated surfaces, by creating an odor, as was explained in the last paper. This objection, however, does not exist with hot water (low pressure) pipes, as the heat is insufficient to scorch the particles in the way described. The trouble, therefore, that dust causes with radiating surfaces heated by hot water is that the particles consist, we may say, wholly and solely, of poor heat-conducting materials, pieces of wood, wool, fibrous and strawlike materials, grit (silica) and various other organic and inorganic substances, that do not conduct heat at all readily. Consequently, a coating of dust acts just like a coating of any of the materials that are occasionally used to prevent dissipation or radiation of heat. The surface of the pipe itself is ready to discharge its heat, but the material resting upon it is opposed to its passage.

There are two remedies for this state of things; one is to keep the pipes clean, which, however, is not done at all willingly or frequently, as it may entail removing large quantities of gratings, etc., every time. In many cases those who attend to the pipes in, say a church, are ignorant of the harmful effect of the dust, and the pipes are only dusted when the accumulation can be seen through the gratings and does not look well. With coils in cases this remedy is not usually possible, as the cases, the ornamental structure provided to inclose and hide the unsightly coil, cannot be removed except by a workman. It would be possible, however, to dislodge the dust with a pair of bellows.

The most common method adopted now to remedy the trouble caused by a lodgment of dust on pipes is to use coils in which the pipes are fixed vertically, that is, upright; dust cannot very well lodge on these at all thickly. This remedy is, however, very limited in application, for it is quite impossible to place the pipes in anything but a horizontal position in almost the majority of cases. The new form of coils known as "radiators" have all upright pipes, with this object in view.

With a hot water apparatus carried out upon what is known as the high pressure system, the water, and consequently the metal of the pipes, attain a fairly high temperature, sometimes 450°. With the pipes of the ordinary low pressure system we seldom get more than 200°. This difference in temperature is often referred to as an objection to the high pressure system, owing to the greater heat giving results somewhat approaching stove heat. This, however, is not strictly correct, for the temperature named, or even 500°, is not sufficient to scorch the materials composing the dust which settles upon the pipes, and the disagreeable odor is not perceivable. Neither does the high pressure system bring about a dryness of the air sufficient to be objectionable for ordinary purposes.

Although the high pressure system of hot water works diffuses heat in the same two ways (radiation and convection) as both stoves and low pressure water works, it is very seldom indeed that the radiant heat is projected into the apartment, as the pipes of this system are, we may say, invariably hidden or covered in some way, usually behind skirtings or else in cases. This style of apparatus answers well for hot air works, that is, heating air in a chamber from whence it is conveyed by pipes or conduits to the points desired. For this purpose it is a little more effective and rapid in results than a system of low pressure pipes, yet it does not require the precautions or have any of the possible disagreeable effects of stove heating.

It is always necessary for hot water pipes to be painted or coated with some material wherever they may be situated, and special need for this arises with the modern radiators referred to, as these being intended to stand in view, with possibly good surroundings, they frequently have to be decorated in an artistic manner with two or three tints or colors. Now, there is a notion somewhat prevalent that color affects radiation; this, however, is practically incorrect as regards non-luminous rays of heat, and we never get luminous rays from hot water pipes (nor from close stoves). Doubtless the idea is due in a great measure to the fact that as lampblack is an excellent radiating material, it might follow that colors ranging from black to light might also range in ratio in their powers of radiation. This would be a natural conclusion, especially as lampblack is classed as the most efficient radiating media we have.

The scale of radiating powers of different substances is as follows: Lampblack, 100; white lead, 100; plumbago (blacklead), 75; cast iron, rough, 60; film of oil, 60; iron, polished, 25; copper, polished, 7.

It has to be impressed upon the reader that by the radiating power of materials is meant the property of diffusing or projecting heat from their surface or skin, and it must be clearly understood that it is in no way related to the action that may take place in the substance of the material. To make this clear, let us suppose that we coated a hot water pipe with a ¼ in. thickness of lampblack; this would give poor results, as lampblack, although possessing excellent radiating qualities, is a bad conductor of heat, and consequently the heat from the pipe would be retarded by the thickness of the black, and very little would get through to the external surface to be radiated. To get effective results, we have to apply the lampblack as a thin coating, then we have the heat from the water readily transferred through the metal of the pipe by the excellent conductive properties of iron, and when it reaches the outside of the pipe, the lampblack will do what is required in projecting the heat into the room. This is effected by the black being applied sparingly, and merely acting as a skin to the pipe.

Lampblack, notwithstanding its good qualities in this direction, can only be used when the pipes are hidden or occupy non-important positions. When it is permissible, it is desirable to use it, and it should be applied as a water color, that is, washed on. For radiating pipes, particularly radiators, occupying conspicuous places, it fortunately happens that oil colors and varnishes, if applied sparingly, give very nearly as good results as lampblack, and this permits us to decorate the radiating material as tastefully as we desire, without impairing efficiency.

With non-luminous rays of heat the color of the radiating medium makes no difference in the amount of heat given off, but the materials composing the colors do. From the table given it will be seen that oils are efficient radiating materials and all oxides and such coloring materials are as good, and we may very safely decorate coils, etc., with ordinary oil color paints, and the gums and shellac used in the manufacture of varnishes have no objectionable features in particular.

Polished metallic surfaces are very bad heat radiators. A copper kettle, for instance (see table just given), will permit of the water within it retaining heat much more efficiently if polished than if oiled and dull. A coating of soot on a copper kettle will make a considerable difference in heat retention, the soot being lampblack to all intents and purposes; it is a good heat dissipator.

As a polished surface is opposed to radiation, it follows that all bronzing and gilding or nickel plating of radiators is likely to give bad or at least less efficient results, and such is really the case. There is no grave objection, however, to having bronze or gilt lines and reliefs on the projecting members of the castings, but if they can be avoided, it is as well, especially as experience will prove that this kind of decoration is inclined to produce a gaudy effect, and is not usually considered to be in such good taste as an arrangement of colors only.

In conclusion, it may be mentioned that as hot water pipes and coils contribute a fair proportion of their heat by convection, that is, by heating the air that comes in contact with them, it follows that the most suitable position for such things is the point where the inflowing air enters an apartment, this usually being the doorway. It is a common and a very desirable plan to heat rooms, when they are of good size, by both open fires and hot water pipes. By this means there need not be an extravagantly large fire kept, but its cheerfulness and other good features are not absent. As mentioned in the previous papers, when an open fire grate is in use, the draught of the chimney induces a somewhat keen inflow of air at some point in the room, and it is usually the doorway that furnishes it, unless any special provision for inlet ventilation exists. This inrush of air, as everyone knows, renders the room unpleasantly draughty by the door, and also across the room from the doorway to the fireplace, necessitating the use of screens, which, however, only divert the current of air from the direct course it was pursuing. The advantage, therefore, gained in introducing hot water pipes is, that by placing them so that they intercept the air as it enters, we impart heat to it, and the unpleasant results explained disappear, and further than this, the heating of the air causes it to take a somewhat less direct passage from door to chimney, and this is a desirable end attained.

It is rather peculiar to note what a number of houses exist with spacious and lofty rooms, yet which (rooms) only have one fireplace in them. In most cases the fireplace is totally unable to heat the room except just at the end where the fire is situated. In other cases the grate may be large enough, but then the heat in the immediate vicinity of the grate itself is intolerable. A grate situated at one end of a large room, yet large enough to heat the whole of the room, gives out an unbearable temperature at the part of the room where the grate is, and a fire of this kind would make an unbearable degree of draught at the doors, etc. With such rooms as these there ought to be two fireplaces, one at each end, or, better still, introduce a coil or radiator by the doorway where the draught enters, as just explained, and this will result in an equable temperature, for the doors are nearly always at the opposite extremities to the fireplaces.

As fireplaces and other causes go to induce an in-passage of air at various points in a house, it is worth a thought as to where this air enters in the first place. In almost every case where no special provision exists, it will be found that the front and back outer doorways, which open into the entrance hall and passages, are the points where the air first enters, and from these points it passes to the different rooms both down and upstairs, and furnishes the needed supply for all purposes. Owing to this it becomes an excellent and always satisfactory plan to have coils or radiators in the entrance hall where this fresh and cold air enters. By this means it can be given a more agreeable temperature, and wherever it passes afterward it will tend to comfort and go a great way toward making all parts of the house warmer. This arrangement gives warmth to the staircases and landings, which are commonly very chilly; and as a hot water boiler can be easily kept going all night, the unpleasant degree of cold felt in the early morning is quite obviated.—*The Building News.*

NUTMEG CULTIVATION.

IN the *Bulletin of the Botanical Department of Jamaica*, for October last, it is stated that a large stock of the very finest nutmegs for seed has been imported to Jamaica from Grenada, and has been sown in the Hope Gardens, and, when ready for distribution, will be sold at the very low rate of three halfpence each, in large or small quantities. It is hoped that these arrangements will tend to develop the planting of nutmegs on a large scale in suitable districts in Jamaica. It is stated that already one order has been filed for 10,000 plants and another for 5,000. The germination of the seed in large quantities, and the care of the seedlings, is said to require the strictest attention, to prevent extensive loss. From the seed beds, the seedlings are transferred to bamboo pots, and, when they have quite recovered from the transplanting, and have formed good roots, they are ready for the nutmeg plantation. The planters must now exercise strict supervision over the laborers, to see that the bamboo pot is carefully slit down on one side, and the plant, with the earth undisturbed round the root, gently placed in the hole prepared for its reception. If this operation is done too harshly or clumsily, the tip of the tap root is broken, and the plant soon dies.

Nutmeg trees require a deep, rich, loamy soil, moist but not swampy, with a humid atmosphere. They thrive best in steady river valleys from sea level up to 300 or 400 feet, but they will grow in favorable situations up to an elevation of 2,000 feet. The trees should be placed at distances of 25 or 30 feet apart, and if the situation is not naturally shady and sheltered trees should be planted for the purpose of breaking the wind, as well as for shade. The trees are a long time coming to maturity, not producing a crop, as a rule, till they are nine years old; and only when they first flower, at six or seven years of age, is it possible to determine whether they are male or female. A very small proportion of male trees is left for fertilization by insects; the rest are cut down, and fresh plants are substituted. The fertile trees continue to produce fruit for seventy or eighty years. On an average, each tree will yield ten pounds of nutmegs and about one pound of mace every year, and, when highly manured, it is said that they will produce ten times that amount.

In connection with the same subject, a note on the curing of nutmegs in Grenada is given in the November number of the *Jamaica Bulletin*, the details of which may be of service to those who are starting the culture. The process is said to be that which is adopted for preparing the nutmegs for the London market. The nutmegs are picked up from under the trees every day, except Sunday. On being brought into the boucan, the mace is peeled off and pressed flat between heavy blocks of wood, where it is left for two or three days, then put into a case and left, till it reaches the proper color. The nutmegs are put into receptacles (with fine mesh bottoms, so that the air can pass through) inside the boucan, and left there for three weeks or a month; in fact, until the nut begins to shake inside the shell. They are then shown the sun for a

couple of hours a day for two or three days. After this they are cracked. Great care is necessary here, for if the outside shell is struck too hard, it makes a black spot in the nutmeg, which affects the value considerably. When cracked the nuts are sorted according to size, put into ordinary flour barrels and shipped. Regarding the value of the produce of nutmeg trees, when in full bearing, it is stated that one grower in 1883 realized from two trees as much as £30.

WYTHES' SEEDLING MELON.

THE raising of melons during the past two or three years has been carried out somewhat largely, and the result is that we have acquired several new kinds that promise to take a permanent place in the list of the finest varieties. Among those who have prosecuted this work with much success is Mr. G. Wythes, of Syon House Gardiens, Brentford; and through the kindness of Messrs. Wm. Cutbush & Son, Highgate, we have an opportunity of illustrating one of the best of the crosses, and named Wythes' seedling. This fine hybrid melon is being distributed by the above firm, and had for one of its parents Limefield Seedling. It has many recommendations, one of its chief characteristics being its earliness, and it sets well, producing shapely fruit, medium in size, the skin of a golden color, netted moderately thickly, and remarkably thin. The flesh cannot be called either scarlet or green, but is a mixture of the two colors, and is of delicious quality, the

MELON, WYTHES' SEEDLING.

flavor everything that can be desired in a good melon. Another good point is its freedom, and amateurs as well as professional gardeners should make a note of it, by reason of its success under very cool conditions in the summer season. This variety has certainly much in its favor, high quality, average size, and fine appearance—three qualifications that make up a fruit of great value. A melon also of excellent quality raised by Mr. Wythes is named Syon House, and forms an important contribution to the scarlet flesh class. It is of remarkably high quality, sets with great freedom, and is of robust constitution, bearing a large crop of oblong shaped fruits, medium in size, the skin yellow, and finely netted. The flesh is of a bright scarlet color, very thick, and of a rich flavor, melting and delicious. It is a cross between Blenheim Orange and Milfield Hybrid, and retains the best qualities of both parents. As it was distributed last year, it is already much grown, and its popularity will increase as its good qualities become more recognized.—*The Gardeners' Magazine.*

THE SANITARY INSTITUTIONS OF PARIS.*

Disinfecting Stations.—When the municipal night refuges of Paris were installed, the administration made it a point to assure the disinfection of the clothing taken off every evening by the beneficiaries. It was obliged to give this service all the extension requisite. The idea occurred to it, as well as to a large number of hygienists, to make of the installations thus annexed to the refuges establishments open likewise to the public. The disinfecting station in Recollets street, and which communicates with the night refuge of Quai Valmy, described in our preceding article, is now the most remarkable establishment of this kind that exists in Paris. Our readers will be so much the more interested in having a description of it, in that we have already pointed out the importance of disinfection for assuring the prophylaxis of contagious diseases. One can easily get an idea of the installation and operation of such establishments, built with great simplicity and ability by Mr. Bouvard, from an inspection of the plan shown in our preceding article.† This general plan clearly shows the establishment as a whole, divided into two distinct parts, separated by a continuous wall. To the left we have the quarters for the reception of the objects to be disinfected, and, to the right, those for the objects that have been disinfected. On the axis and flanking Recollets street, there is a special pavilion reserved for the administration, and giving special access to each of the two quarters.

When the wagons sent from A return from the dwelling that has called for them, they enter through the court, B, and as soon as one of the disinfectors accompanying has rung at the external gate, they run under the unloading porch, C. The objects having been deposited in the store room, H, the wagons pass into the court, D, where they, as well as the horses, are disinfected. After the horses have been unharnessed and disinfected they are taken to the stable, S, at the end of the yard to the right, and the wagons are placed in the house, A. Between the latter and the unloading porch there are arranged, at E and G, beyond the storehouse, dressing rooms, *lavabos* and privies for the use of the employes in charge of the wagons. The same accessories are provided for the *personnel* charged with the disinfection of the wagons, along with a dining hall near by and a room for the drivers overhead.

The contaminated objects are received in the hall, H. If it is necessary, they are submitted (linen particularly) to a rinsing in a special back. Then they are placed in the carriage of one of the steam stoves set into the central wall. After being taken out through the doors at N, the disinfected objects are placed upon screens running along the walls of the room. The disinfecting *materiel* is completed by an incinerator for worthless objects, and by vaporizers. An installation, I J K, of toilet rooms, *lavabos*, and cleansing apparatus is provided for the use of the workmen, who, when they wish to go out of doors, pass through a special corridor running to the street. Moreover, communication between the part that receives the contaminated objects and the one in which the objects are deposited after disinfection can be effected only through a passage, M, divided into three parts and provided with a *lavabo* in the center, and the doors of which can never both be opened at the same time. The office of the general superintendent is at O, and his dwelling place at L.

The objects are sent out in wagons that start from T, and which are drawn by one of the horses whose stable is at R. The load is taken on at one of the doors of the hall, N. The dining room of the *personnel* of this part of the establishment is at P.

The objects that are sent out from the refuge every night to be disinfected are received at U, in the court, D, and, after an antiseptic treatment, return to the refuge through the gate, V.

This description suffices to give an idea of the separation carefully established between the two parts of the disinfecting station, one of which receives the infected objects and the other the disinfected. The sole communications possible between the two parts are effected through the interior of stoves and through passageways with locks that no one can enter except by asking permission, and after having cleansed himself antiseptically and divested himself of the special clothing obligatory for a stay in the contaminated rooms.

The processes of disinfection used in this establishment are as follows: Passage through the stove heated by steam under pressure, and cleansing by means of a vaporizer containing a 1-1000 solution of corrosive sublimate to which is added tartaric acid in the proportion of 75 grains to the quart, and a few drops of an alcoholic tincture of carmine or indigo.

We have had occasion in these pages to show our readers that disinfection through steam under pressure constitutes the most efficacious, most rapid and most practical process that we know of to-day for destroying all pathogenic micro-organisms and all the germs of contagious diseases contained in clothing, mattresses, etc. The apparatus used are those of Geneste & Herscher, and which are now employed by the government and a large number of cities and public administrations, both French and foreign. After fifteen minutes of steam heating and fifteen minutes of drying, the disinfection is complete.

As for the vaporizers, which also are constructed by the same house, they are designed to project the antiseptic liquid in a very fine spray over all objects that cannot be placed in the stove, such as leather, furs, etc., and also to disinfect rooms and their contents. With the solution mentioned above, this mode of disinfection is done rapidly, without any injury even to objects of high price, provided the operation be performed with some care. The perfect efficiency of this process has been many times demonstrated. It is destined to replace disinfection through sulphurous acid gas, which is a difficult, always incomplete, and illusory process in the conditions of current practice, and so lengthy as to render the use of it much more injurious than useful as regards the generalization of disinfection.

The municipal disinfecting stations of Paris are open to the public gratuitously, either whether one carries the contaminated objects thither directly or requests the employes to come to the house for the objects, and, what is indispensable, to disinfect the house at the same time. The service is performed by special men, whose experience has been tested, and it is supervised with much care by Mr. Menant, the director of municipal affairs.

The following are the various operations that have to be practiced for effecting a disinfection in case of contagious diseases. The enumeration of them may seem long, but provided one gives them some attention, it will be readily seen how simple they are and how rapidly they can be performed.

When the wagon starts, the disinfectors must be sure that it contains the following *materiel:* (1) The vaporizer pump and several bottles containing the disinfecting liquid, which are confided to their care and responsibility and must never be intrusted to any one else, no matter who it may be; (2) a bottle containing a quart of solution of permanganate of potash in the proportion of 12 grains to 1,000; (3) a canvas bag containing the working costume, say for each man a canvas cap, a canvas blouse adjusted to the neck and wrists, a pair of canvas trousers, and shoes; (4) several wrappers closed in any way except by leather cords, and which must be of different forms for mattresses, bolsters, pillows, coverlets, etc., and be marked with numbers or letters in red, of large size; (5) rags designed for wiping purposes; (6) two large sponges, a scrub brush and a brush with a handle; (7) a tool bag; and (8) a jointed ladder provided with rubber at the extremities of the uprights.

As soon as they reach the house, the disinfectors carry their *materiel* to the room to be disinfected, and put on their working clothes before entering it. They first, with a brush, scour the linen spotted with blood, with the aid of the permanganate solution, after which they put into wrappers all the objects that are to be

FIG. 2.—DISINFECTION OF A BEDROOM.

carried to the stove, such as mattresses, bed clothes, linen, curtains, clothing, etc. Then, after pouring the contents of one of the bottles into the vaporizer pump and after filling the latter with water, they project (Fig. 2) a spray of disinfecting liquid against the walls, floors, wood work, carpets, furniture (especially the beds), night tables, and all the other objects left in the room.

No portion of the rooms to be disinfected nor any of the objects that they contain must be neglected.

The mirrors and their frames, the pictures and art objects, have to be rubbed with rags that have been dipped in the disinfecting solution. The carpets and the hangings left in the house on account of their bulk have to be removed and treated on both sides with a spray of the disinfecting fluid. The floor or the walls that they cover have likewise to be disinfected. The vessels and utensils that have been used by the patient, as well as the water closets and toilet tables, have to be washed with the disinfecting solution.

After these operations are finished, the disinfectors must take off their working clothes and put them in the bag provided for them, and take them to the disinfecting stove, along with the bags containing the objects that are likewise to be placed in the stove. As soon as the objects to be disinfected reach the establishment, it is unloaded and the whole must, as soon as possible, be disinfected as we have explained above (Fig. 1). After disinfection, the objects are carried back as soon as possible to the house of their owner by the wagon especially designed for the purpose.

Such is the programme followed in great part by the disinfecting service of the municipal station. All the details of this programme have their importance, and it is because they can be carefully executed by such service that the latter is the only one that is now capable of inspiring confidence in the citizens of Paris.

Under the penalty of being in a measure useless, without real effect, and even dangerous, the disinfec-

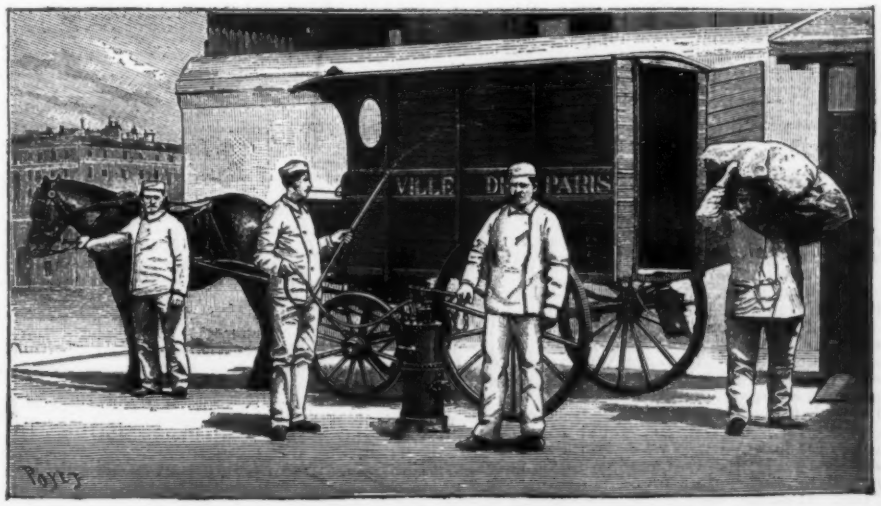


FIG. 1.—UNLOADING AND DISINFECTING A WAGON BELONGING TO A DISINFECTING STATION AT PARIS

*Continued from SUPPLEMENT, No. 842, page 13455.

† See SUPPLEMENT, No. 842, page 13456.

tion must be practiced with all these precautions. It is unfortunately not thus when one applies to certain concerns which, taking advantage of the silence of the law and the absence of police surveillance, do not fear, at great expense to their customers, to apply the name of disinfection to their illusory processes. This happens with every installation except that of the municipal stations under control of the prefecture of the Seine.

These stations are fortunately beginning to be more and more appreciated by the public services, the mayoralty, physicians, and the public, for the number of their operations is constantly increasing and amounts on an average to twenty-five a day, fifteen of which are in the Recollet street station, illustrated in our preceding article. They are as yet too few to assume the prophylaxis of all the cases of contagious diseases in Paris, and it would be impossible to make them too widely known, for disinfection is the most efficacious of all sanitary measures. Thanks to such services, it may be practiced in all cases properly and radically.

It is not without interest to add that a certain number of French cities have already organized similar services. Several have even found therein an appreciable source of revenue by charging a certain amount to people in easy circumstances.—*La Nature.*

TETRA-IODIDE OF CARBON.

TETRA-IODIDE of carbon, CI_4, has been obtained in large ruby-red crystals by M. Moissan by the action of his recently prepared boron iodide, BI_3, upon carbon tetrachloride. Boron iodide is a substance crystallizing from solution in carbon bisulphide in colorless tabular crystals which melt at 43° to a liquid boiling at 210°. It is a substance of great chemical activity, reacting with considerable energy with a large number of substances. When it is brought in contact with carbon tetrachloride, double decomposition occurs in the cold, with a large evolution of heat, boron chloride and carbon tetra-iodide being formed.

$$4BI_3 + 3CCl_4 = 4BCl_3 + 3CI_4.$$

The best mode of operating is to heat the two substances, the crystals of boron iodide and excess of dry redistilled carbon tetrachloride, in a sealed tube for one hour at a temperature of 80°—90°. Next morning the tube is found to contain large crystals of carbon tetra-iodide, which appears to be produced in theoretical quantity. After opening the tube, the crystals are drained, washed with a solution of bisulphite of soda in order to remove the last traces of iodine, and finally dried *in vacuo*. When the red crystals thus obtained are heated to 100° in an exhausted sealed tube, they slowly sublime into the colder portion of the tube in magnificent brilliant red crystals very much resembling the artificial rubies prepared by MM. Fremy and Verneuil. The reactions of carbon tetra-iodide are somewhat interesting. When heated in a current of hydrogen at a temperature about 140°, it is reduced to iodoform, CHI_3.

$$CI_4 + H_2 = CHI_3 + HI.$$

When the crystals are placed in an atmosphere of chlorine they at once liquefy, and the liquid becomes hot. The products are carbon tetrachloride and liquid chloride of iodine, ICl, which latter gradually volatilizes away in the form of the chloride, ICl_3.

$$CI_4 + 4Cl_2 = CCl_4 + 4ICl.$$

When heated gently in dry oxygen, it becomes decomposed into iodine and carbon, which latter burns away to carbon dioxide upon slightly raising the temperature. Melted sulphur reacts with carbon tetra-iodide with considerable violence; vapor of iodine is evolved, carbon deposited, and iodide of sulphur formed. If, however, powdered sulphur is warmed with carbon tetra-iodide to 50°, iodide of sulphur and carbon bisulphide are produced. Phosphorus acts with great energy upon it, forming compounds which are still undergoing investigation. Sodium and potassium react with incandescence, an alkaline iodide and free carbon being produced. Mercury and silver likewise attack it at the ordinary temperature, and very rapidly upon warming. Warm hydrochloric and hydriodic acids attack the crystals rapidly, with formation of iodoform and liberation of vapor of iodine. A particularly interesting reaction is that with fluoride of silver. When a quantity of this salt is placed in a solution of carbon tetra-iodide in carbon tetrachloride warmed to 50°, a regular evolution of gaseous carbon tetrafluoride occurs.

$$CI_4 + 4AgF = CF_4 + 4AgI.$$

This reaction affords the readiest means yet discovered of preparing carbon tetrafluoride.—*Nature.*

SODAMMONIUM.

A CURIOUS compound of lead, sodium, and ammonia, $Pb_4Na_2NH_3$, is described by M. Joannis in the current number of the *Comptes Rendus*. M. Joannis has been studying the nature and reactions of the substance known as sodammonium, obtained by dissolving metallic sodium in liquefied ammonia. The deep blue liquid thus produced has been shown in a previous communication (see *Nature*, vol. xliii., p. 399) to decompose slowly at the ordinary temperature into hydrogen gas and sodamide, a compound of the composition $NaNH_2$, which M. Joannis isolated in the form of colorless crystals. That such a compound as sodammonium ($NaNH_3$)$_n$, really exists in the blue solution in liquefied ammonia would appear to be the most natural assumption from these experiments. The reactions of sodammonium now described lend additional support to this view. When a rod of pure lead is placed in a saturated solution of sodammonium in water, the reddish brown liquid becomes rapidly blue, and finally assumes a deep green tint. A small quantity of hydrogen is evolved at the same time, owing to the decomposition of a portion of the sodammonium into sodamide, as above described. The lead gradually disappears, and a solid substance possessing an indigo blue color is deposited. This blue substance is found upon analysis to consist of the compound $Pb_4Na_2NH_3$, and would appear to be a sodammonium in which a portion of the sodium is replaced by lead. It dissolves readily in liquefied ammonia, with formation of a solution possessing a bottle-green tint. It is not very stable, dissociating spontaneously on standing, with production of a gray substance very much resembling spongy platinum. Upon exposure to air it becomes warm, owing to its rapid oxidation. It behaves in a somewhat remarkable manner toward water. When introduced in small quantities at a time into ordinary water, the first portions dissolve completely, the oxygen dissolved in the water oxidizing the lead to litharge, which at once dissolves in the alkaline solution formed. As soon, however, as the oxygen in the water is used up, further additions of the substance result in the precipitation of black flocculæ of metallic lead. Another interesting reaction of sodammonium is that with metallic mercury, which behaves in an entirely different manner from lead. When the solution of sodammonium in liquefied ammonia is poured over a globule of mercury, rapid action occurs, with the ultimate elimination of the whole of the ammonia, and production of a sodium amalgam of the composition $NaHg_2$, which has been obtained in well formed crystals. This reaction is the more interesting inasmuch as M. Berthelot, from purely thermo-chemical considerations, has previously indicated the possible existence of such a compound of sodium and mercury.—*Nature.*

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